Crooked Creek and Lost Creek Watershed Total Maximum Daily Load

DRAFT Stage 1 Report

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Acronyms and Abbreviations

AFO	animal feeding operation
AWQMN	Ambient Water Quality Monitoring Network
BOD	biochemical oxygen demand
CAFO	confined animal feeding operation
CBOD	carbonaceous biochemical oxygen demand
CWA	Clean Water Act
DMR	discharge monitoring record
DO	dissolved oxygen
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
ISU	Iowa State University
L	liter
mg	milligram
µg	microgram
MCL	Maximum Contaminant Level
MGD	millions of gallons per day
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
SOD	sediment oxygen demand
STEPL	Spreadsheet Tool for Estimating Pollutant Load
STP	sewage treatment plant
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
U.S. EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WQS	water quality standards
WWTP	wastewater treatment plant

1. Introduction

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that Total Maximum Daily Loads (TMDLs) be developed for waters that do not support their designated uses. In simple terms, a TMDL is a plan to attain and maintain water quality standards in waters that are not currently meeting standards. This TMDL study addresses a portion of the Crooked Creek watershed in southern Illinois. The project area, referred to as the Crooked Creek watershed, is approximately 563 square miles (Figure 1). A previous TMDL study was completed in the Crooked Creek watershed, and relevant information from the study is included herein where applicable (Illinois EPA 2008).

1.1 TMDL Development Process

The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream conditions. This allowable loading represents the maximum quantity of the pollutant that the waterbody can receive without exceeding water quality standards. The TMDL also includes a margin of safety, which reflects uncertainty, as well as the effects of seasonal variation. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and nonpoint sources, and restore and maintain the quality of their water resources (U.S. EPA 1991).

The Illinois EPA will be working with stakeholders to implement the necessary controls to improve water quality in the impaired waterbodies and meet water quality standards. It should be noted that the controls for nonpoint sources (e.g., agriculture) will be strictly voluntary.

1.2 Water Quality Impairments

Several waters in the Crooked Creek watershed have been placed on the State of Illinois §303(d) list (Table 1 and Figure 1). There are other segments listed on the §303(d) that are not addressed by this project. A previous TMDL (Illinois EPA 2008) addressed the dissolved oxygen (DO) impairment in segment OJ-07; however, a TMDL was not developed.

Table 1. Crooked Creek and Lost Creek watershed impairments and pollutants (2016 Illinois 303(d) Draft List)

Name	Segment ID	Segment Length (Miles)	Watershed Area (Sq. Miles)	Designated Uses	Cause of Impairment
Kaskaskia River	IL_O-07	17.85	2,759	Aquatic Life	**Dissolved Oxygen**, Phosphorus (Total)
Kaskaskia River	IL_O-25	14.65	3,283	Aquatic Life	**Dissolved Oxygen**
				Public and Food Processing Water Supply	**Simazine**
Crooked Creek	IL_OJ-07	34.46	185	Aquatic Life	**Dissolved Oxygen,** Phosphorus (Total)
Crooked Creek	IL_OJ-08	24.34	466	Aquatic Life	Iron [a], Phosphorus (Total), Total Suspended Solids (TSS)
Crooked Creek	IL_OJ-11	15.72	31	Aquatic Life	**Dissolved Oxygen**
Lost Creek	IL_OJB-04	25.75	78	Aquatic Life	**Dissolved Oxygen,** Phosphorus (Total), Sedimentation/Siltation
Prairie Creek	IL_OJBA	21.8	31	Aquatic Life	**Dissolved Oxygen,** Phosphorus (Total)
Grand Point Creek	IL_OJC-01	16.55	66	Aquatic Life	**Dissolved Oxygen**, Sedimentation/Siltation
Raccoon Creek	IL_OJF	17.08	53	Aquatic Life	**Dissolved Oxygen**
Salem Lake	IL_ROR	74 ac (surface area)	4	Aquatic Life	**pH**, Total Suspended Solids (TSS)
				Public and Food Processing Water Supply	Simazine

BOLD – TMDLs are addressed in this Stage 1 report.
a. Based on evaluation of the last ten years of available iron data (2007–2016), it was determined that segment IL_OJ-08 does not need an iron TMDL (see Appendix A – Unimpaired Stream Data Analysis).

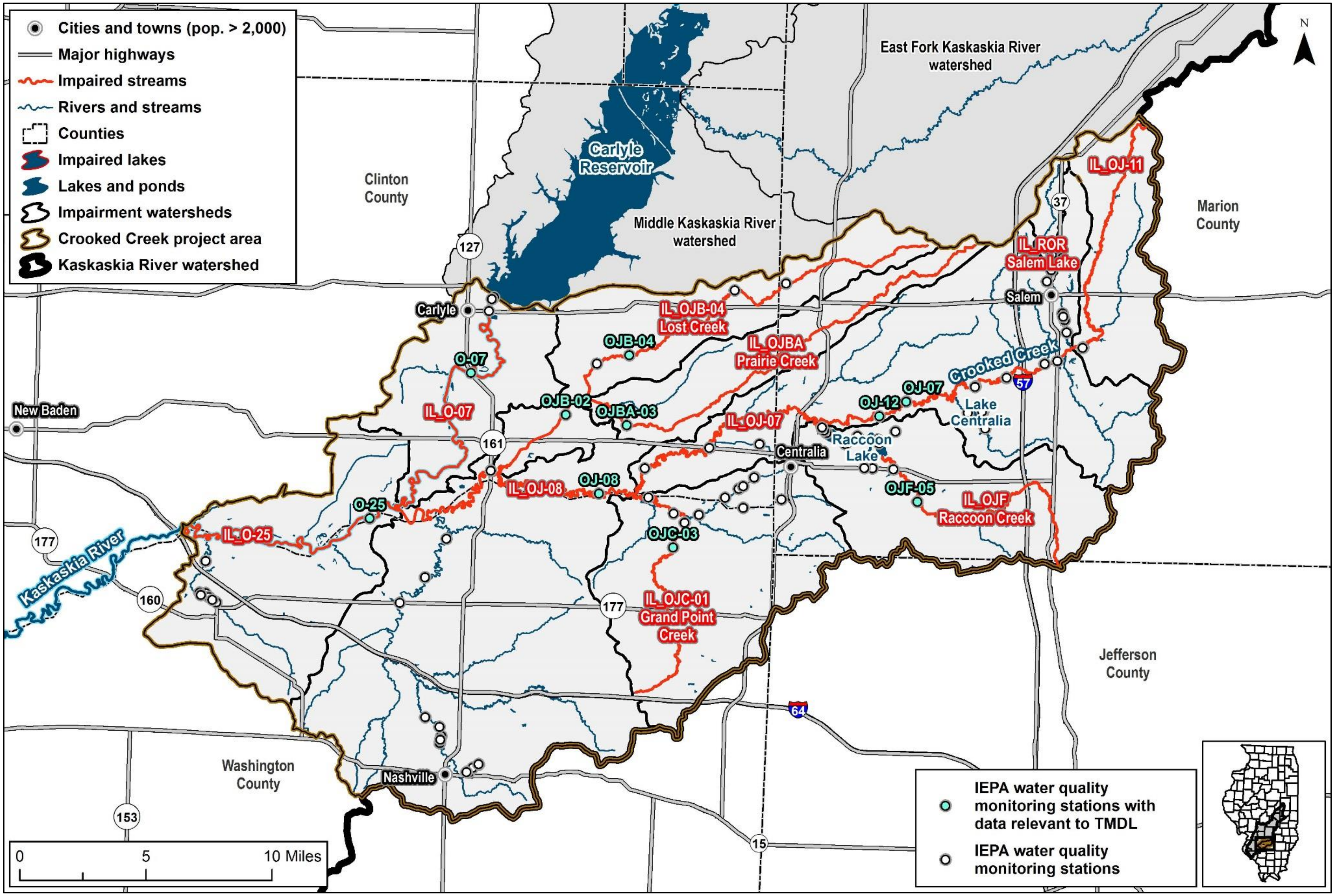

Figure 1. Crooked Creek watershed, TMDL project area.

1.3 TMDL Endpoints

This section presents information on the water quality standards (WQS) that are used for TMDL endpoints. WQS are designed to protect beneficial uses. The authority to designate beneficial uses and adopt WQS is granted through Title 35 of the Illinois Administrative Code. Designated uses to be protected in surface waters of the state are defined under Section 303, and WQS are designated under Section 302 (Water Quality Standards). Designated uses and WQS are discussed below.

1.3.1 Designated Uses

Illinois EPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB) to assess the designated use support for Illinois waterbodies. The following are the use support designations provided by the IPCB that apply to waterbodies in the Crooked Creek watershed:

General Use Standards – These standards protect for aquatic life, wildlife, agricultural uses, primary contact (where physical configuration of the waterbody permits it, any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing), secondary contact (any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating, and any limited contact incident to shoreline activity), and most industrial uses. These standards are also designed to ensure the aesthetic quality of the state's aquatic environment.

Public and food processing water supply standards – These standards are cumulative with the general use standards and apply to waters of the state at any point at which water is withdrawn for treatment and distribution as a potable supply to the public or for food processing.

1.3.2 Water Quality Standards and TMDL Endpoints

Environmental regulations for the State of Illinois are contained in the Illinois Administrative Code, Title 35. Specifically, Title 35, Part 302 contains water quality standards promulgated by the IPCB. This section presents the standards applicable to impairments in the study area. Water quality standards are the endpoints to be used for TMDL development in the Crooked Creek watershed (Table 2).

Table 2. Summary of water quality standards for the Crooked Creek watershed

Parameter	Units	General Use Water Quality Standard
Dissolved Oxygen [a]	mg/L	March-July > 5.0 min. and > 6.0- 7-day mean Aug-Feb > 3.5 min, > 4.0- 7-day mean and > 5.5- 30-day mean If less than 10 samples, not to exceed two violations of the standard. If greater than 10 samples, not to exceed one violation of the standard.
pH	s.u.	Within the range of 6.5–9.0 except for natural causes
Sizamine	µg/L	Not to exceed Maximum Contaminant Level of 4 µg/L
Iron, Dissolved	µg/L mg/L	Acute standard < 1,000 µg/L < 0.3 mg/L, and 1.0 mg/L Maximum Contaminant Level for waters supplies serving >/= 1,000 people or >/= 300 connections

a. Applies to the dissolved oxygen concentration in the main body of all streams, in the water above the thermocline of thermally stratified lakes and reservoirs, and in the entire water column of unstratified lakes and reservoirs.

General Use Standards

Aquatic life use assessments in streams are typically based on the interpretation of biological information, physicochemical water data and physical-habitat information from the Intensive Basin Survey, Ambient Water Quality Monitoring Network, or Facility-Related Stream Survey programs. The primary biological measures used are the fish Index of Biotic Integrity (Karr et al. 1986; Smogor 2000, 2005), the macroinvertebrate Index of Biotic Integrity (Tetra Tech 2004), and the Macroinvertebrate Biotic Index (Illinois EPA 1994). Physical habitat information used in assessments includes quantitative or qualitative measures of stream bottom composition and qualitative descriptors of channel and riparian conditions. Physicochemical water data used include measures of conventional parameters (e.g., dissolved oxygen, pH, and temperature), priority pollutants, non-priority pollutants, and other pollutants (U.S. EPA 2002 and www.epa.gov/wqc). In a minority of streams for which biological information is unavailable, aquatic life use assessments are based primarily on physicochemical water data.

When a stream segment is determined to be Not Supporting aquatic life use, generally one exceedance or violation of an applicable Illinois WQS (related to the protection of aquatic life) results in identifying the parameter as a potential cause of impairment. Additional guidelines used to determine potential causes of impairment include site-specific standards (35 Ill. Adm. Code 303, Subpart C) or adjusted standards (published in the ICPB's Environmental Register at https://pcb.illinois.gov/Resources/EnvironmentalRegister).

Public and Food Processing Water Supply Standards

Attainment of public and food processing water supply use is assessed only in waters in which the use is currently occurring, as evidenced by the presence of an active public-water supply intake. The assessment of public and food processing water supply use is based on conditions in both untreated and treated water. By incorporating data through programs related to both the federal Clean Water Act and the federal Safe Drinking Water Act, Illinois EPA believes that these guidelines provide a comprehensive assessment of public and food processing water supply use. Assessments of public and food processing water supply use recognize that characteristics and concentrations of substances in Illinois surface waters can vary and that a single assessment guideline may not protect sufficiently in all situations. Using multiple assessment guidelines helps improve the reliability of these assessments. When applying these assessment guidelines, Illinois EPA also considers the water-quality substance, the level of treatment available for that substance, and the monitoring frequency of that substance in the untreated water. Table 3 includes the assessment guidelines for waters with public and food processing water supply designated uses.

Table 3. Guidelines for assessing public water supply in waters of the State (Illinois EPA 2016)

Degree of Use Support	Guidelines
Fully Supporting (Good)	For each substance in untreated water[a], for the most-recent three years of readily available data or equivalent dataset, a) < 10% of observations exceed an applicable Public and Food Processing Water Supply Standard[b]; and b) for which the concentration is not readily reducible by conventional treatment, i) no observation exceeds by at least fourfold the treated-water Maximum Contaminant Level threshold concentration[c] for that substance; and ii) no quarterly average concentration exceeds the treated-water Maximum Contaminant Level threshold concentration[c] for that substance; and iii) no running annual average concentration exceeds the treated-water Maximum Contaminant Level threshold concentration[d] for that substance; and[d] For each substance in treated water, no violation of an applicable Maximum Contaminant Level[c] occurs during the most recent three years of readily available data.
Not Supporting (Fair)	For any single substance in untreated water[a], for the most-recent three years of readily available data or equivalent dataset, a) > 10% of observations exceed a Public and Food Processing Water Supply Standard[b]; or b) for which the concentration is not readily reducible by conventional treatment, i) at least one observation exceeds by at least fourfold the treated-water Maximum Contaminant Level threshold concentration[c] for that substance; or ii) the quarterly average concentration exceeds the treated-water Maximum Contaminant Level threshold concentration[c] for that substance; or iii) the running annual average concentration exceeds the treated-water Maximum Contaminant Level threshold concentration[c] for that substance. or, For any single substance in treated water, at least one violation of an applicable Maximum Contaminant Level[3] occurs during the most recent three years of readily available data.
Not Supporting (Poor)	Closure to use as a drinking-water resource (cannot be treated to allow for use).

a. Includes only the untreated-water results that were available in the primary computer database at the time data were compiled for these assessments
b. 35 I11. Adm. Code 302.304, 302.306 (ftp://www.ilga.gov/jcar/admincode/035/03500302sections.html)
c. 35 I11. Adm. Code 611.300, 611.301, 611.310, 611.311, 611.325.
d. Some waters were assessed as Fully Supporting based on treated-water data only.

One of the assessment guidelines for untreated water relies on a frequency-of-exceedance threshold (10 percent) because this threshold represents the true risk of impairment better than does a single exceedance of a water quality criterion. Assessment guidelines also recognize situations in which water treatment that consists only of "*...coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes*" (35 Ill. Adm. Code 302.303; hereafter called "conventional treatment") may be insufficient for reducing potentially harmful levels of some substances. To determine if a Maximum Contaminant Level (MCL) violation in treated water would likely occur if treatment additional to conventional treatment were not applied (see 35 Ill. Adm. Code 302.305), the concentration of the potentially harmful substance in untreated water is examined and compared to the MCL threshold concentration. If the concentration in untreated water exceeds an MCL-related threshold concentration, then an MCL violation could reasonably be expected in the absence of additional treatment.

Compliance with an MCL for treated water is based on a running 4-quarter (i.e., annual) average, calculated quarterly, of samples collected at least once per quarter (Jan.–Mar., Apr.–Jun., Jul.–Sep., and Oct.–Dec.). However, for some untreated-water intake locations sampling occurs less frequently than once per quarter; therefore, statistics comparable to quarterly averages or running 4-quarter averages cannot be determined for untreated water. Rather, for substances not known to vary regularly in concentration in Illinois surface waters (untreated) throughout the year, a simple arithmetic average concentration of all available results is used to compare to the MCL threshold. For substances known to vary regularly in concentration in surface waters during a typical year (e.g., simazine), average concentrations in the relevant sub-annual (e.g., quarterly) periods are used.

2. Watershed Characterization

The Crooked Creek watershed is located in southern Illinois (Figure 1); the headwaters begin just north of the city of Salem, IL. Crooked Creek joins the Kaskaskia river upstream of Shelbyville Lake, and the Kaskaskia River eventually joins the Mississippi River south of St. Louis, Missouri. A TMDL has been developed for the Crooked Creek watershed (Illinois EPA 2008), and much of the information presented in that report is applicable to the Crooked Creek project area. There have been no known changes in the project area; therefore, the previous TMDL provides much of the basis for the watershed characterization and source assessment for the Crooked Creek project area below.

2.1 Jurisdictions and Population

Counties with land located in the watershed include Clinton, Jefferson, Marion, and Washington. Cities in the watershed include Centralia, Salem, Nashville, and Carlyle. Populations are area weighted to the watershed in Table 4. The Clinton County and Jefferson County population numbers were adjusted to account for cities in each county that are outside of the watershed.

Table 4. Area weighted county populations in watershed

County	2000 Population	2010 Population	Percent Change
Clinton	6,674	7,072	6%
Jefferson	195	194	-1%
Marion	14,445	13,664	-5%
Washington	5,710	5,547	-3%
TOTAL	***27,024***	***26,477***	***-2%***

Source: U.S. Census Bureau

2.2 Climate

In general, the climate of the region is continental with hot, humid summers and cold winters. Relevant information on climate can be found in the completed Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008).

2.3 Land Use and Land Cover

Land use in the watershed is heavily influenced by agriculture (Figure 2). Urban areas are located primarily near the cities of Centralia, Salem, Nashville, Carlyle, and several small towns in the watershed. Land use in the watershed includes cultivated crops, pasture/hay, forest, and urban (Table 5). Corn and soybeans are the most common crops, with much smaller areas of winter wheat, alfalfa, and other crops.

Table 5. Watershed land use summary

Land Use / Land Cover Category	Acres	Percentage
Cultivated Crops	186,079	51.7%
Hay/Pasture	63,947	17.8%
Deciduous Forest	51,749	14.4%
Developed, Open Space	22,739	6.3%
Developed, Low Intensity	13,191	3.7%
Woody Wetlands	12,497	3.5%
Developed, Medium Intensity	3,578	1.0%
Open Water	3,167	0.9%
Herbaceous	1,747	0.5%
Developed, High Intensity	1,175	0.3%
Emergent Herbaceous Wetlands	116	<0.1%
Evergreen Forest	51	<0.1%
Barren Land	19	<0.1%

Source: 2011 National Land Cover Database (MLRC 2015)

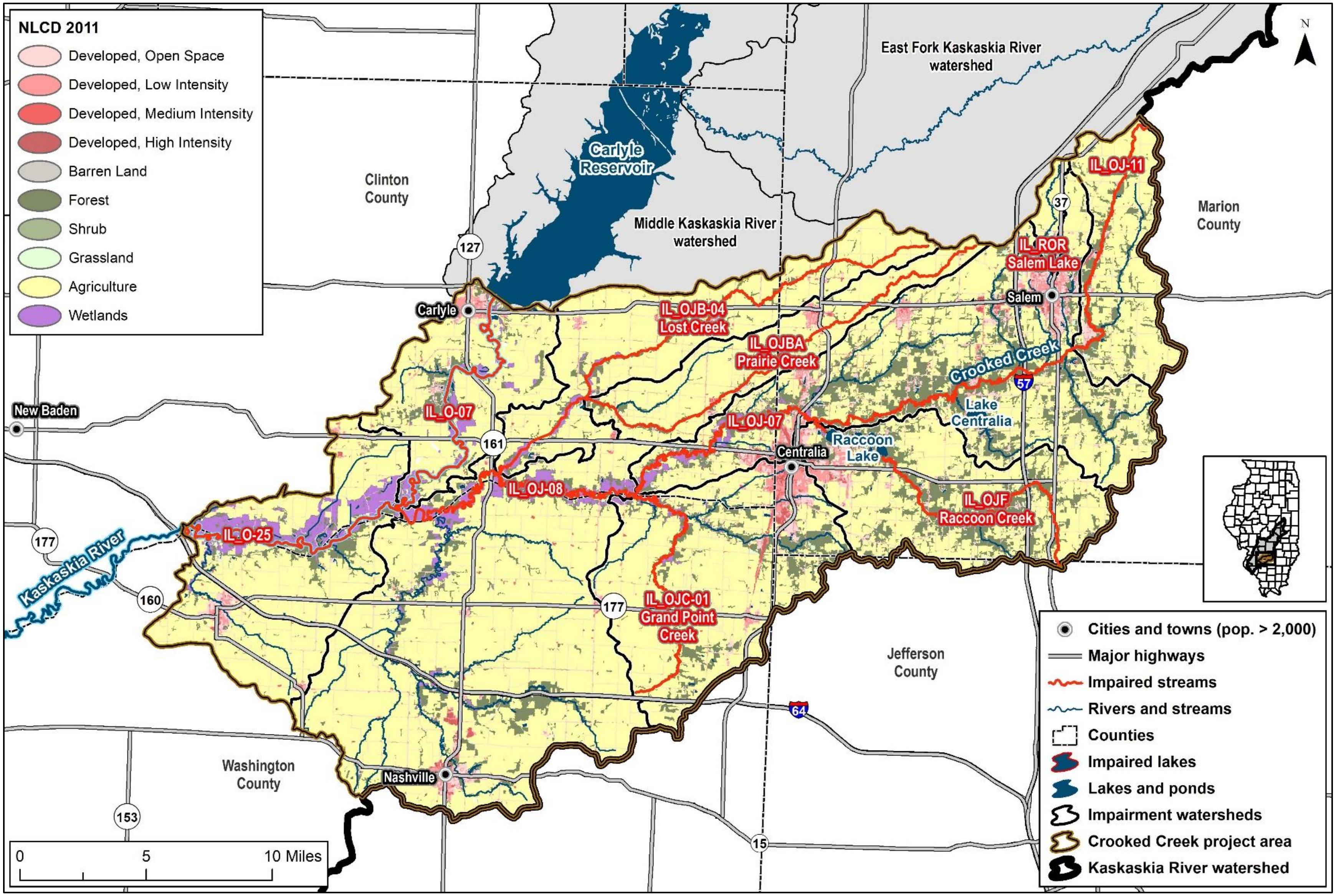

Figure 2. Crooked Creek watershed land cover (2011 National Land Cover Database)

2.4 Topography

Relevant information on topography can be found in the completed Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008).

2.5 Soils

Relevant information on soils can be found in the recently completed Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008). Much of the watershed is made up of fine-grained, silt and clay soils.

2.6 Hydrology

Relevant information on hydrologic conditions can be found in the completed Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008). Active U.S. Geological Survey (USGS) flow gage sites are located along Crooked Creek segment OJ-08 (05593520) and on the OJA-01 segment of Little Crooked Creek (05593575).

2.7 Watershed Studies and Information

This section describes several of the studies that have been completed in the watershed:

- **Crooked Creek Watershed Total Maximum Daily Load Report** (Illinois EPA 2008)

  The completed Crooked Creek TMDL Report contains relevant information and data for this TMDL. Causes of impairments included dissolved oxygen, manganese, pH, total phosphorus, and atrazine.

- **Kaskaskia River Watershed, An Ecosystem Approach to Issues and Opportunities** (Southwestern Illinois RC&D, Inc. 2002)

  The plan encompasses the larger Kaskaskia River watershed from Champaign County to Randolph County in southwestern Illinois, covering over 10 percent of the state of Illinois. The purpose of the plan was to begin a coordinated restoration process in the Kaskaskia River watershed based on sound ecosystem principles. The plan made recommendations on sustainability, diversity, health, variety, connectivity, and the ecosystem's ability to thrive and reproduce in order to promote the sustainability of the ecosystem and strengthen the economic base and the quality of life of residents in the region.

3. Watershed Source Assessment

Source assessments are an important component of water quality management plans and TMDL development. Point sources typically discharge at a specific location from pipes, outfalls, and conveyance channels. Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters, particularly overland runoff. This section provides a summary of potential point and nonpoint sources that contribute to the impaired waterbodies.

3.1 Pollutants of Concern

Pollutants of concern evaluated in this source assessment include simazine, iron, and parameters influencing dissolved oxygen and pH. Dissolved oxygen in streams can be affected by biochemical oxygen demand, phosphorus, ammonia, and sediment oxygen demand in addition to non-pollutant causes such as a lack of reaeration. These pollutants can originate from an array of sources including point and nonpoint sources. Eutrophication (high levels of algae) is also often linked directly to low dissolved oxygen conditions and high pH, and therefore nutrients are also a pollutant of concern.

3.2 Point Sources

Point source pollution is defined by the Federal Clean Water Act (CWA) §502(14) as:

> *"any discernible, confined and discrete conveyance, including any ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation [CAFO], or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agriculture storm water discharges and return flow from irrigated agriculture."*

Under the CWA, all point sources are regulated under the National Pollutant Discharge Elimination System (NPDES) program. A municipality, industry, or operation must apply for an NPDES permit if an activity at that facility discharges wastewater to surface water. Point sources can include facilities such as sewage treatment plants (STPs), industrial facilities, concentrated animal feeding operations (CAFOs), or regulated storm water including municipal separate storm sewer systems (MS4s). There is one CAFO in the Crooked Creek watershed (Permit # ILA010075) near Plum Creek, a tributary to Kaskaskia River segment (O-25), which is impaired for simazine and dissolved oxygen. There are no permitted MS4s in the Crooked Creek watershed.

There are eighteen individual NPDES permitted facilities in the Crooked Creek project area (Table 6). Six facilities discharge directly to impaired segments. Average and maximum design flows and downstream impairments are included in the facility summaries. Additional information on existing permitted sources can be found in the Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008).

Table 6. Individual NPDES permitted facilities discharging to impaired segments

IL Permit ID	Facility Name	Type of Discharge	Receiving Water	Downstream Impairment(s)	Average Design Flow (MGD)	Maximum Design Flow (MGD)
IL0023264	*Salem STP*	*STP outfall*	*Tom Creek*	*OJ-07*	*2.508*	*7.023*
ILG580187	*Odin STP*	*STP outfall*	*Turkey Creek*	*OJ-07*	*0.195*	*1.8*
ILG640031	*Salem WTP*	*Public water supply*	*Town Creek*	*OJ-07*	*0.253* [a]	–
IL0075884	*Huey STP*	*STP outfall*	*Unnamed tributary to Lost Creek*	*OJB-04*	*0.0289*	*0.1157*
ILG580277	**Junction City STP**	**STP outfall**	**Prairie Creek**	**OJBA**, OJB-04	**0.06**	**0.15**
ILG580205	**Hoffman STP**	**STP outfall**	**Prairie Creek**	**OJBA,** OJB-04	**0.06**	**0.15**
IL0030961	**Sandoval STP**	**STP outfall**	**Prairie Creek**	**OJBA,** OJB-04	**0.18**	**0.45**
IL0053040	*Foster's MHP*	*Mobile home park-STP*	*Unnamed tributary to South Creek*	*OJ-07*	*0.0024*	*0.006*
ILG640247	**Centralia WTP**	**Public water supply**	**Crooked Creek**	**OJ-07**	**0.662** [a]	–

IL Permit ID	Facility Name	Type of Discharge	Receiving Water	Downstream Impairment(s)	Average Design Flow (MGD)	Maximum Design Flow (MGD)
IL0027979	*Centralia STP*	*STP outfall*	*Sewer Creek*	*OJC-01*	*3.15*	*4.5*
ILG580144	*Wamac STP*	*STP outfall*	*Fulton Branch*	*OJC-01*	*0.15*	*0.6*
IL0000779	*IL Central RR Centralia*	*Maintenance shop and fueling area stormwater, yard stormwater*	*Fulton Creek*	*OJC-01*	*0.023* [a]	–
IL0071242	*United Parcel Service*	*Vehicle wash water*	*Unnamed tributary to Fulton Branch*	*OJC-01*	*0.0001* [a]	–
IL0052981	*Raccoon Consolidated School*	*STP outfall*	*Unnamed tributary to Raccoon Creek*	*OJF, OJ-07*	*0.0125*	*0.031*
ILG580265	*Central City STP*	*STP outfall*	*Unnamed tributary to Raccoon Creek*	*OJF, OJ-07*	*0.304*	*1.267*
IL0049140	*Addieville STP*	*STP outfall*	*Plum Creek-North*	*O-25*	*0.033*	*0.083*
ILG580268	*Okawville WWTP*	*STP outfall*	*Unnamed tributary to Plum Creek-North*	*O-25*	*0.25*	*0.877*
IL0027901	**Carlyle STP**	**STP outfall**	**Kaskaskia River**	**O-07,** O-25	**0.709**	**1.30**
ILG551030	Western Gardens MHP-Centralia	STP outfall	U-Trib Crooked Creek	OJ-07	0.01875	0.048

a. Average design flow based on average reported flow from 2014–2016 discharge monitoring records (DMRs)
-- No design flow available.
Italics – NPDES facility draining to unimpaired segment.
BOLD – NPDES facility draining to impaired segment.
STP – Sewage treatment plant
MGD – Million gallons per day

3.3 Nonpoint Sources

The term nonpoint source pollution is defined as any source of pollution that does not meet the legal definition of point sources. Nonpoint source pollution typically results from overland stormwater runoff that is diffuse in origin, as well as background conditions. As part of the water resource assessment process, Illinois EPA has identified several sources as contributing to the Crooked Creek watershed impairments (Table 7). Some of these sources do not contribute pollutants, but do affect the waterbody's ability to support biota such as loss of riparian habitat and impacts from flow regulation or modification.

Table 7. Potential sources in project area based on the Draft 2016 305(b) list

Name	Segment	Impairment	Sources
Kaskaskia River	IL_O-25	Simazine	Crop production (crop land or dry land), agriculture, atmospheric deposition – toxics, and source unknown
Crooked Creek	IL_OJ-07	Dissolved oxygen	Crop production (crop land or dry land) and agriculture
Crooked Creek	IL_OJ-11	Dissolved oxygen	Source unknown
Lost Creek	IL_OJB-04	Dissolved oxygen	Loss of riparian habitat, crop production (crop land or dry land), and agriculture
Prairie Creek	IL_OJBA	Dissolved oxygen	Loss of riparian habitat, streambank modification/destabilization, livestock, (grazing or feeding operations), crop production (crop land or dry land), agriculture, pesticide application, and urban runoff/storm sewers
Grand Point Creek	IL_OJC-01	Dissolved oxygen	Animal feeding operations (nonpoint source), loss of riparian habitat, livestock (grazing or feeding operations), crop production (crop land or dry land), and agriculture
Raccoon Creek	IL_OJF	Dissolved oxygen	Impacts from hydrostructure flow regulation/modification and agriculture
Salem Lake	IL_ROR	pH	Littoral/shore area modifications (non-riverine), waterfowl, crop production (crop land or dry land), urban runoff/storm sewers

3.3.1 Stormwater and Agricultural Runoff

During wet-weather events (snowmelt and rainfall), sediment and pollutants are incorporated into runoff and can be delivered to downstream waterbodies. The resultant pollutant loads are linked to the land uses and practices in the watershed. Agricultural and developed areas can have significant effects on water quality if proper best management practices are not in place. These areas contribute high biochemical oxygen demand and nutrients that can affect the dissolved oxygen conditions in streams and pH in lakes. Drain tiles also transport agricultural runoff directly to ditches and streams, whereas runoff flowing over the land surface may infiltrate to the subsurface and may flow through riparian areas. Pesticides applied to both agricultural and urban landscapes can also contribute to low dissolved oxygen conditions.

Simazine is an herbicide that is widely used in agricultural fields. All sources of simazine are assumed to be nonpoint sources resulting from application to cropland. The half-life of simazine in soil ranges from 36 to 234 days. Further, simazine readily dissolves in water and weakly bonds to soil particles, resulting in transmittal in environments with high runoff potential or persistence and transport to groundwater in soils with high water content (USDA 1990). It is also possible that simazine can be released from manufacturing, formulation, transport, and disposal.

3.3.2 Animal Feeding Operations (AFOs)

Animal feeding operations that are not classified as CAFOs are known as animal feeding operations (AFOs) in Illinois. Non-CAFO AFOs are considered nonpoint sources by U.S. EPA. AFOs in Illinois do not have state permits. However, they are subject to state livestock waste regulations and may be inspected by the Illinois EPA, either in response to complaints or as part of the agency’s field inspection responsibilities to determine compliance by facilities subject to water pollution and livestock waste regulations. The animals raised in AFOs produce manure that is stored in pits, lagoons, tanks, and other storage devices. The manure is then applied to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. AFOs, however, can pose environmental concerns, including the following:

- Manure can leak or spill from storage pits, lagoons, tanks, etc.
- Improper application of manure can contaminate surface or ground water.
- Manure over application can adversely impact soil productivity.

Livestock are potential sources of bacteria and nutrients to streams, particularly when direct access is not restricted and/or where feeding structures are located adjacent to riparian areas. Watershed specific data are not available for livestock populations. However, county wide data available from the 2012 Census of Agriculture were downloaded and area weighted to estimate the animal population in the project area. An estimated 6,615 animals are in the project area.

3.3.3 Internal Loads

Internal loading of pollutants can occur in both streams and lakes, leading to impaired conditions. In streams, sediment oxygen demand takes up oxygen from the water column as a result of organic decomposition. In lakes, phosphorus is released from the lake bottom as a result of anoxic conditions or physical disturbances. This load of phosphorus, when added to external sources of nutrients to a lake, can result in algal blooms affecting the pH of a lake.

3.3.4 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons and can contribute to low dissolved oxygen conditions and lake impairments. Common soil-type limitations that contribute to failure include seasonally high water tables, compact glacial till, bedrock, and fragipan. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsely and Witten 1996). Septic systems contain all the water discharged from homes and businesses and can be significant sources of pollutants.

Relevant information for this section can be found in the completed Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008). In addition, county health departments were contacted for information on septic systems and unsewered communities. In Jefferson County, 99 new systems or replacements were put in during 2017, and there are approximately 15 to 25 nuisance complaints each year. No new information was provided for the other counties.

4. Water Quality

Background information on water quality monitoring can be found in the completed Crooked Creek Watershed Total Maximum Daily Load report (Illinois EPA 2008). In the Crooked Creek project area, water quality data were found for numerous stations that are part of the Illinois EPA Ambient Water Quality Monitoring Network (AWQMN). Monitoring stations with data relevant to the impaired segments are presented in Figure 1 and Table 8. Parameters sampled in the streams include field measurements (e.g., dissolved oxygen) as well as those that require lab analyses (e.g., iron).

The most recent 10 years of data collection, 2007–2016, were used to evaluate impairment status. Additional continuous dissolved oxygen data for 2012 and 2017 were provided by Illinois EPA and used to evaluate dissolved oxygen impairments where available. Data that are greater than 10 years old are not included. Each data point was reviewed to ensure the use of quality data in the analysis below. Data were obtained directly from Illinois EPA. No data were available to assess impairment for Kaskaskia River (O-25; simazine) and Salem Lake (ROR; pH).

Table 8. Crooked Creek watershed water quality data

Waterbody	Impaired Segment	Pollutant	AWQMN Sites	Location	Period of Record
Kaskaskia River	IL_O-07	Dissolved Oxygen	O-07	River mile 87.8, Route 127 Branch 3 miles South of Carlyle	2012[a], 2017[a]
	IL_O-25	Dissolved Oxygen	O-25	River mile 74.8, 2.5 miles north of Covington	2012[a], 2017[a]
		Simazine	No available data		
Crooked Creek	IL_OJ-07	Dissolved Oxygen	OJ-07, OJ-12	Odin Rd (500E) Branch, 0.7 miles north of Green St Rd and 3.5 mile south of Odin, 3 miles east of Central City	2007, 2012
	IL_OJ-08	Iron	OJ-08	Hoffman Rd. Branch 2.5 miles southwest of Hoffman	2007-2016
	IL-OJ-11	Dissolved Oxygen	No available data		
Lost Creek	IL_OJB-04	Dissolved Oxygen	OJB-02, OJB-04	2 miles northwest of Hoffman, 3.5 miles northeast of Hoffman	2007, 2017[a]
Prairie Creek	IL_OJBA	Dissolved Oxygen	OJBA-03	Creek Rd 0.6 miles northeast of Hoffman	2007
Grand Point Creek	IL_OJC-01	Dissolved Oxygen	OJC-03	3.9 miles northwest of Irvington on Sycamore Rd.	2007, 2017[a]
Raccoon Creek	IL_OJF	Dissolved Oxygen	OJF-05	Copple Rd Branch 2 miles north of Walnut Hill	2012
Salem Lake	IL_ROR	pH	No available data		

a. Continuous DO data were received from Illinois EPA for 2012 and 2017 and used to evaluate impairment status where available.

An important step in the TMDL development process is the review of water quality conditions, particularly data and information used to list segments. Examination of water quality monitoring data is a key part of defining the problem that the TMDL is intended to address. This section provides a brief review of available water quality information provided by the Illinois EPA.

4.1 Kaskaskia River (O-07)

Kaskaskia River segment O-07 is listed as impaired for aquatic life due to dissolved oxygen. One sample site (sample site O-07) has dissolved oxygen data along the segment. Continuous dissolved oxygen data were collected in July and September 2012 and June, July, and August 2017 (Figure 3). Greater than 10 percent of the samples and the 7-day mean in July 2012 violated the standard. No additional violations of the standard were observed. Aquatic life use impairment is verified along this segment.

Further review of available information was conducted to evaluate the potential causes of impairment. Carlyle STP (IL002791) discharges to the segment and may be contributing to impairment (Table 6). There are also upstream impairments that could potentially be related to the downstream dissolved oxygen impairment. O-07 is also listed as impaired due to phosphorus (see Table 1). Dissolved oxygen data were paired with phosphorus data to determine if eutrophication is potentially contributing to low dissolved oxygen conditions. Chlorophyll-*a* data are limited along the segment and are not included. Data older than 10 years were included in the analysis based on the assumption that conditions have not changed along the segment. Phosphorus versus dissolved oxygen data collected from 1999–2016 shows a negative correlation, indicating that eutrophication could be contributing to low dissolved oxygen conditions along the segment (Figure 4).

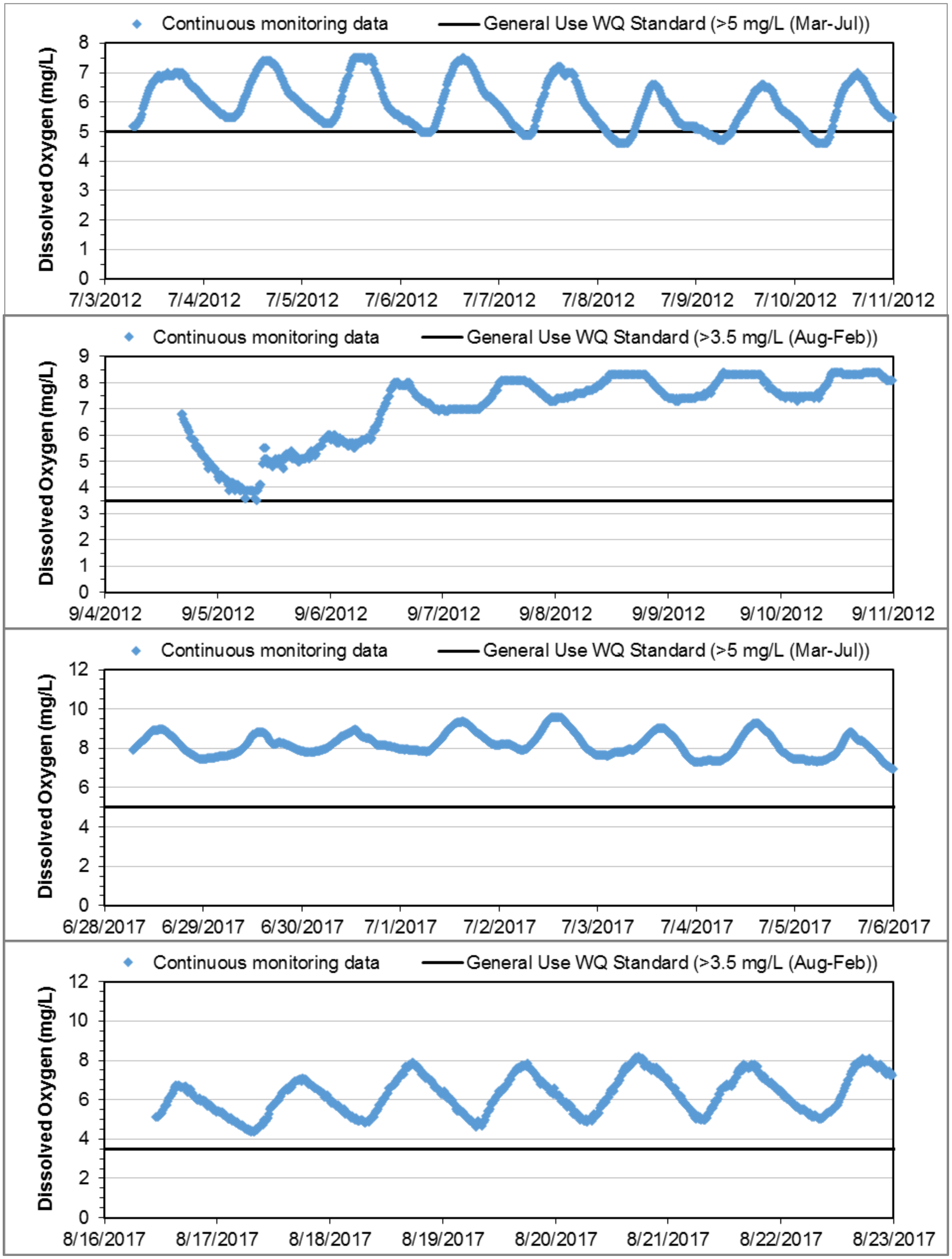

Figure 3. Continuous water quality time series for dissolved oxygen, Kaskaskia River O-07.

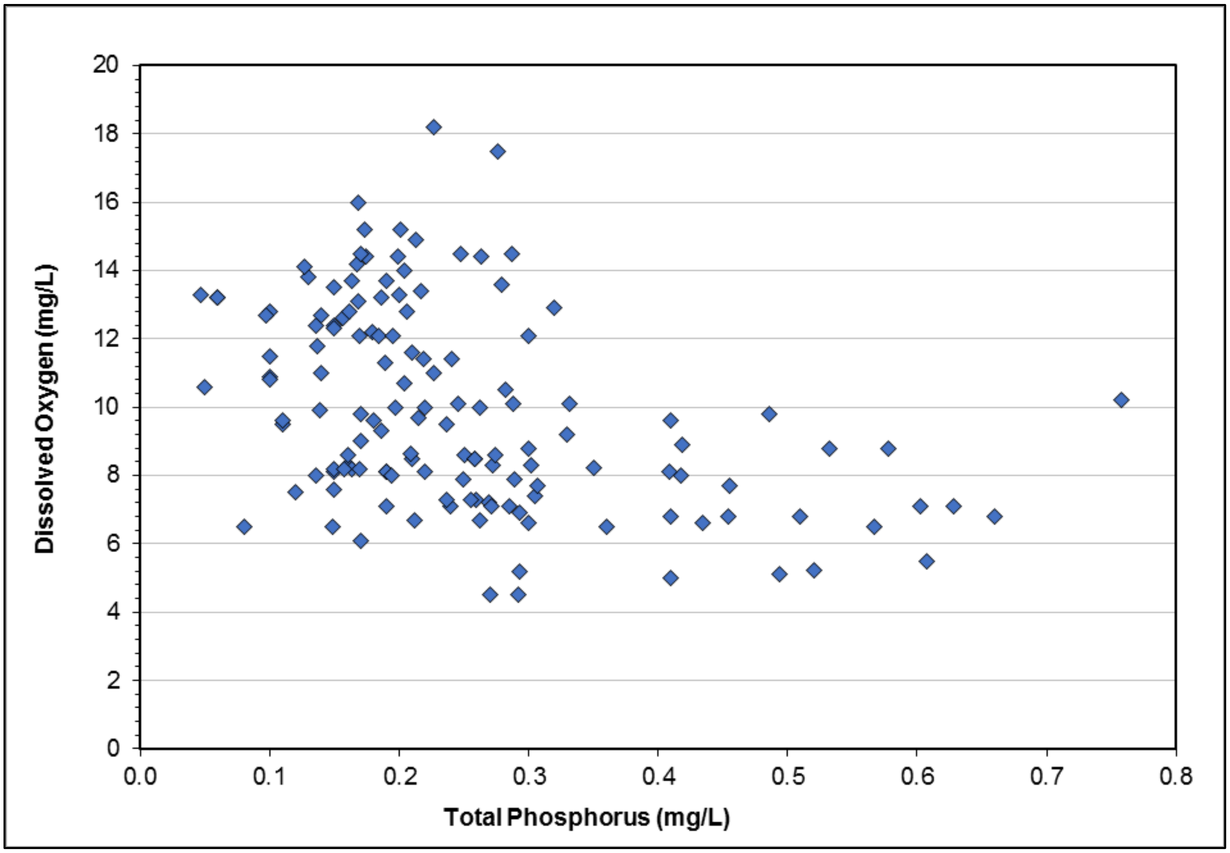

Figure 4. Total phosphorus versus dissolved oxygen—1999–2016, Kaskaskia River O-07.

4.2 Kaskaskia River (O-25)

The Kaskaskia River (O-25) is listed as impaired for public and food processing water supply due to simazine. There are no simazine data available on the impaired segment. One sample site (sample site O-07) on Kaskaskia River (O-07), located directly upstream of segment O-25, has simazine data. Of the 75 simazine samples collected on segment O-07 between 2007 and 2016, there were no exceedances of the general use water quality standard. The listing is based on Syngenta/USEPA simazine data collected from the Nashville intake (IN01357), which indicate a quarterly average greater than 4 µg/L.

Kaskaskia River segment O-25 is also listed as impaired for aquatic life due to dissolved oxygen. One sample site (sample site O-25) has dissolved oxygen data along the segment. Continuous dissolved oxygen data were collected in July and September 2012 and June, September, and October 2017 (Figure 5). Greater than 10 percent of the samples in July 2012 violated the standard. No additional violations of the standard were observed. Aquatic life use impairment is verified along this segment.

Further review of available information was conducted to evaluate the potential causes of impairment. No wastewater treatment facilities discharge to the segment. There are upstream impairments that could potentially be related to the downstream dissolved oxygen impairment. Paired dissolved oxygen and phosphorus data show a correlation indicating that eutrophication could be contributing to low dissolved oxygen conditions along the segment (Figure 6). A phosphorus target will be derived from the relationship presented in Figure 6 to develop a total phosphorus TMDL that will address the low dissolved oxygen conditions along O-25.

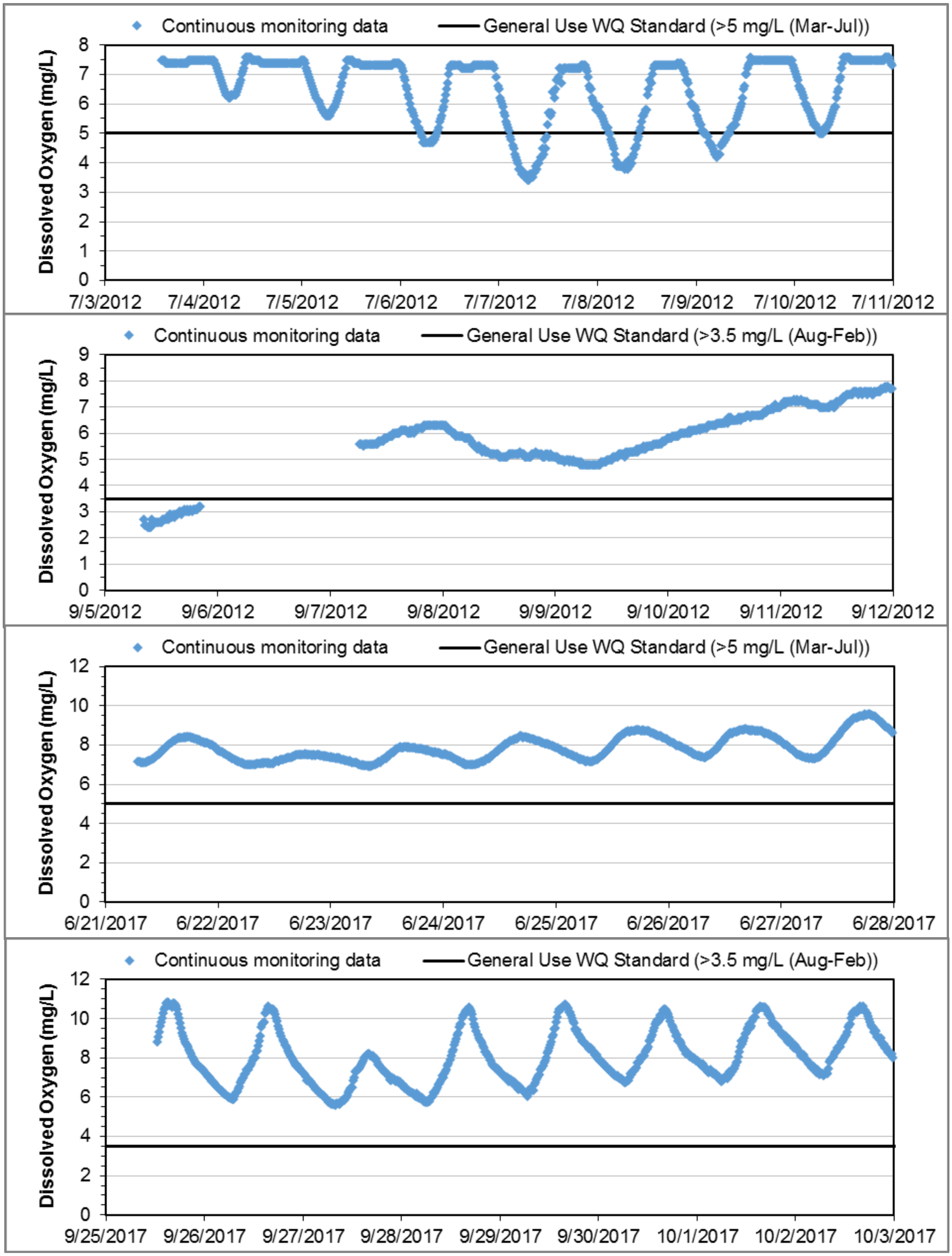

Figure 5. Continuous water quality time series for dissolved oxygen, Kaskaskia River O-25.

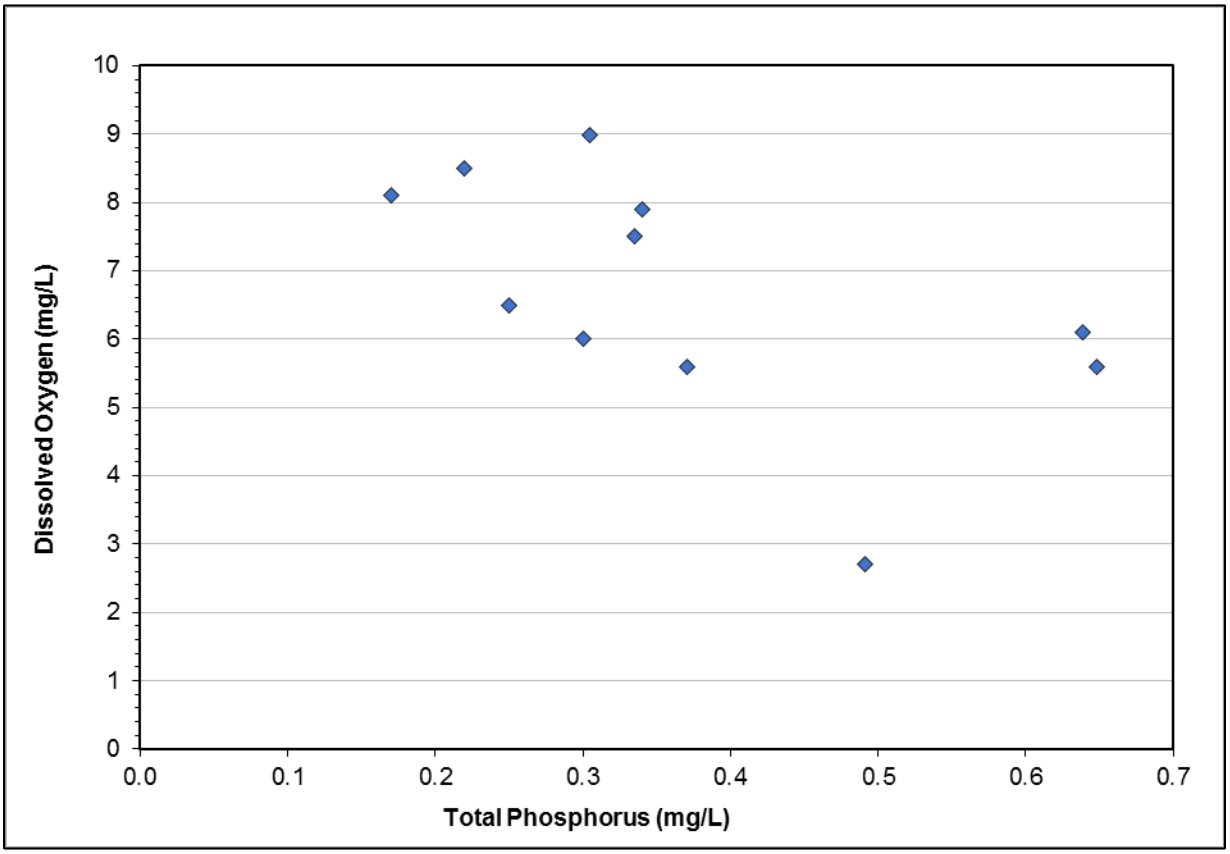

Figure 6. Total phosphorus versus dissolved oxygen—2002, 2007, and 2012, Kaskaskia River O-25.

4.3 Crooked Creek (OJ-07)

Crooked Creek is listed as impaired for aquatic life due to dissolved oxygen along segment OJ-07. Two sample sites (sample sites OJ-7 and OJ-12) have dissolved oxygen data along the segment (Table 9 and Figure 7). One violation of the general use water quality standard for dissolved oxygen was observed in August 2012; however, to verify impairment on segments with fewer than ten samples, two or more violations of the general use water quality standard are needed. Therefore, additional data are needed to verify impairment.

Table 9. Data summary, Crooked Creek OJ-07

Sample Site	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of violations of general use water quality standard (>5 mg/L (Mar-Jul) and >3.5 mg/L (Aug-Feb))
Dissolved oxygen					
OJ-07	2	5.4	8.6	11.8	0
OJ-12	2	3.1	5.8	8.4	1

Further review of available information was conducted to evaluate the potential causes of impairment. No wastewater treatment facilities discharge to the impaired segment; Western Gardens MHP–Centralia

(ILG551030) discharges to a tributary in close proximity to segment IL_OJ-07. There are upstream impairments that could potentially be related to the downstream dissolved oxygen impairment.

OJ-07 is also listed as impaired due to phosphorus (see Table 1). There is no clear relationship between paired dissolved oxygen and phosphorus data (Figure 8). Note that samples older than 10 years are plotted on Figure 8; it is assumed that the relationship between phosphorus and dissolved oxygen has not changed significantly over time.

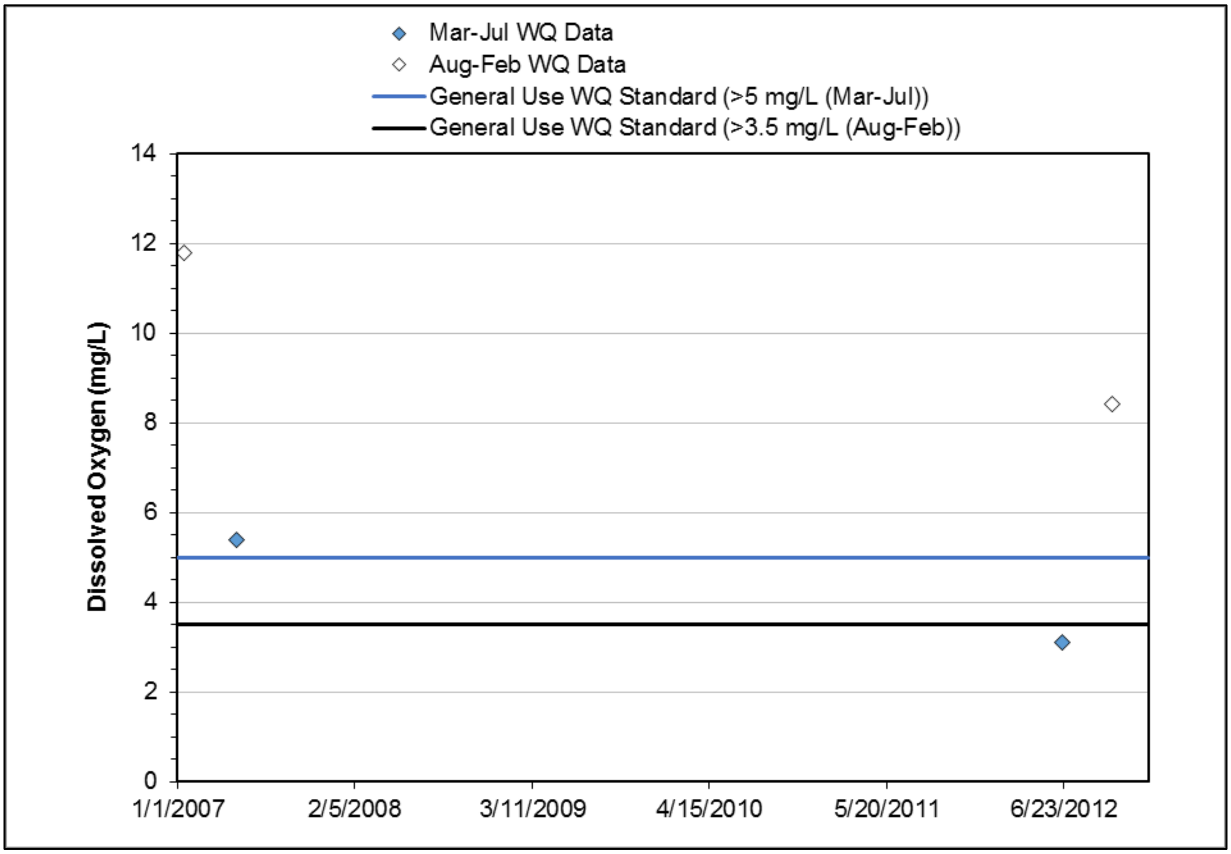

Figure 7. Dissolved oxygen water quality time series, Crooked Creek OJ-07.

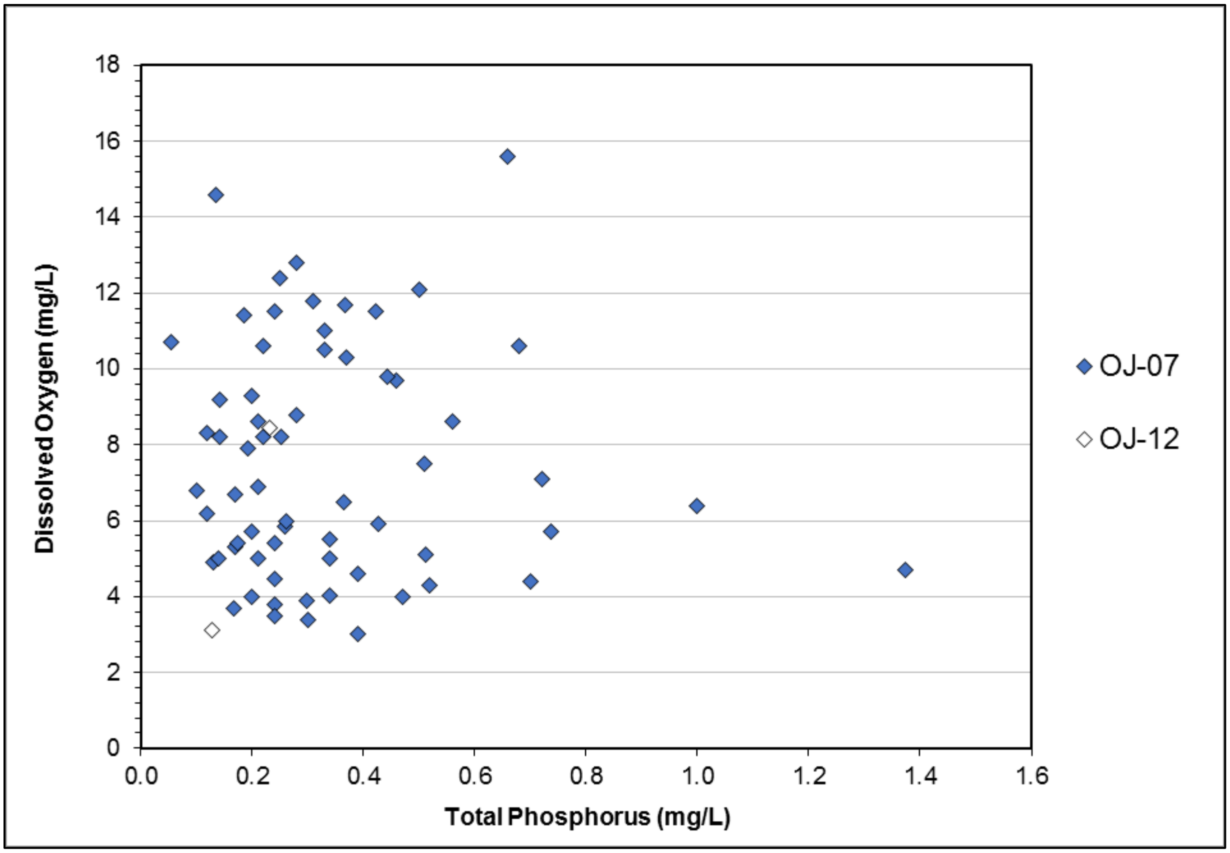

Figure 8. Total phosphorus versus dissolved oxygen—1999–2012, Crooked Creek OJ-07.

4.4 Crooked Creek (OJ-11)

Crooked Creek is listed as impaired for aquatic life due to dissolved oxygen along segment OJ-11. There were no dissolved oxygen data collected on OJ-11; additional data collection is needed to verify the dissolved oxygen impairment on segment OJ-11. No wastewater treatment facilities discharge to the segment.

4.5 Lost Creek (OJB-04)

Lost Creek is listed as impaired for aquatic life due to dissolved oxygen along segment OJB-04. There are two Illinois EPA sampling sites located on segment OJB-04 with dissolved oxygen data. Three dissolved oxygen grab samples were collected between 2007 and 2012 (Table 10 and Figure 9). Two violations of the general use water quality standard for dissolved oxygen were observed in August and September 2007. Continuous dissolved oxygen data were collected in July and August 2017 (Figure 10). Greater than 10 percent of the samples and the 7-day mean during both time periods violated the standard. Aquatic life use impairment is verified along this segment.

Table 10. Data Summary, Lost Creek OJB-04

Sample Site	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of violations of general use water quality standard (>5 mg/L (Mar-Jul) and >3.5 mg/L (Aug-Feb))
Dissolved oxygen					
OJB-04	1	7.1	7.1	7.1	0
OJB-02	2	1.7	2.0	2.3	2

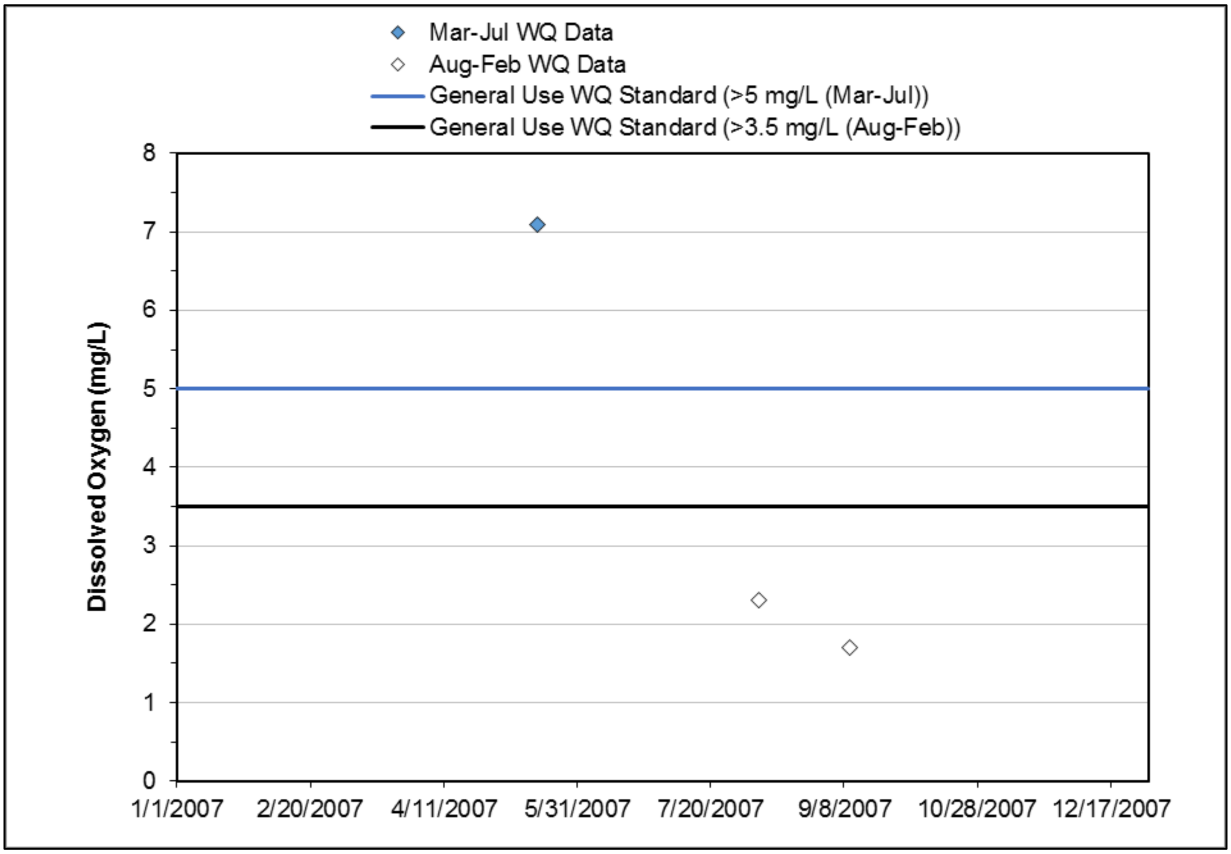

Figure 9. Dissolved oxygen water quality time series, Lost Creek OJB-04.

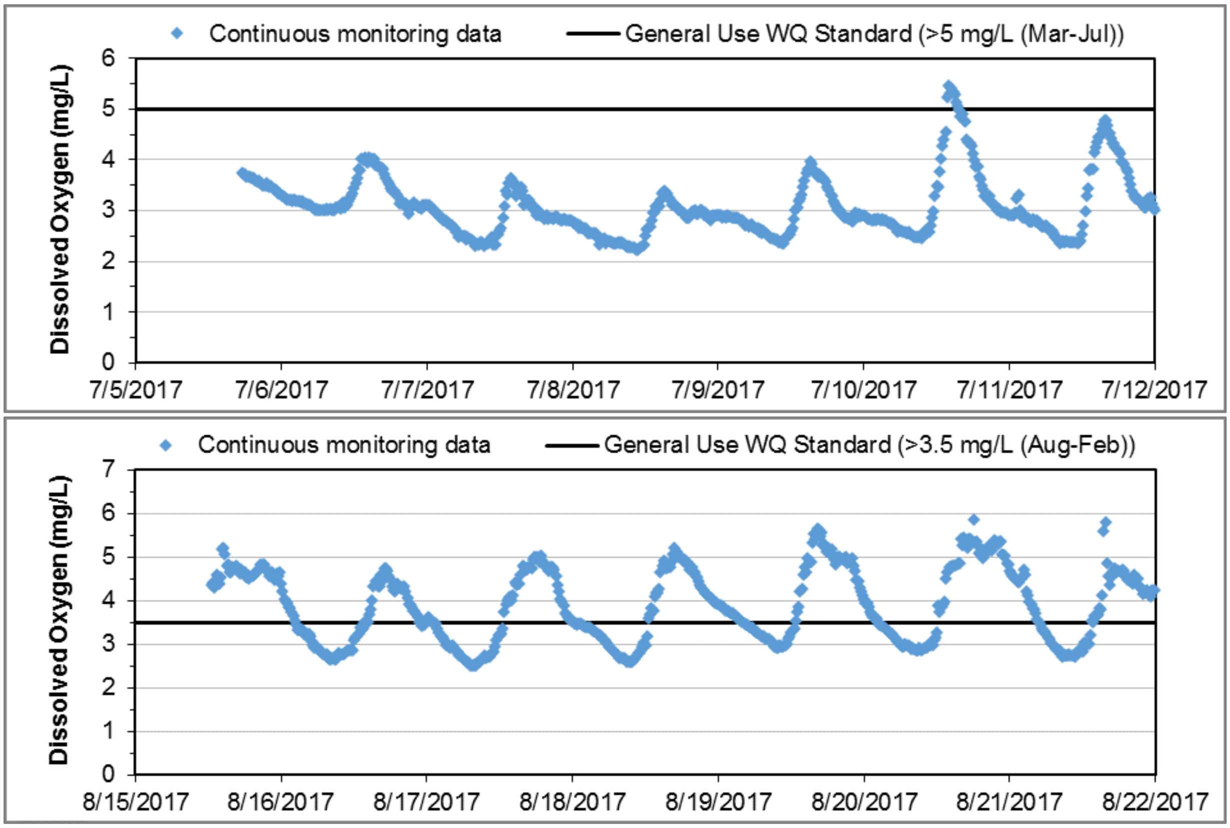

Figure 10. Continuous water quality time series for dissolved oxygen, Lost Creek OJB-04.

Further review of available information was conducted to evaluate the potential causes of impairment. No wastewater treatment facilities discharge to the segment. There are upstream impairments that could potentially be related to the downstream dissolved oxygen impairment.

OJB-04 is also listed as impaired due to phosphorus (see Table 1). Dissolved oxygen data were paired with phosphorus data to determine if eutrophication is potentially contributing to low dissolved oxygen conditions. Data older than 10 years were included in the analysis based on the assumption that conditions have not changed along the segment. Phosphorus versus dissolved oxygen data collected from 2002–2007 indicate that phosphorus levels may negatively impact dissolved oxygen (Figure 11).

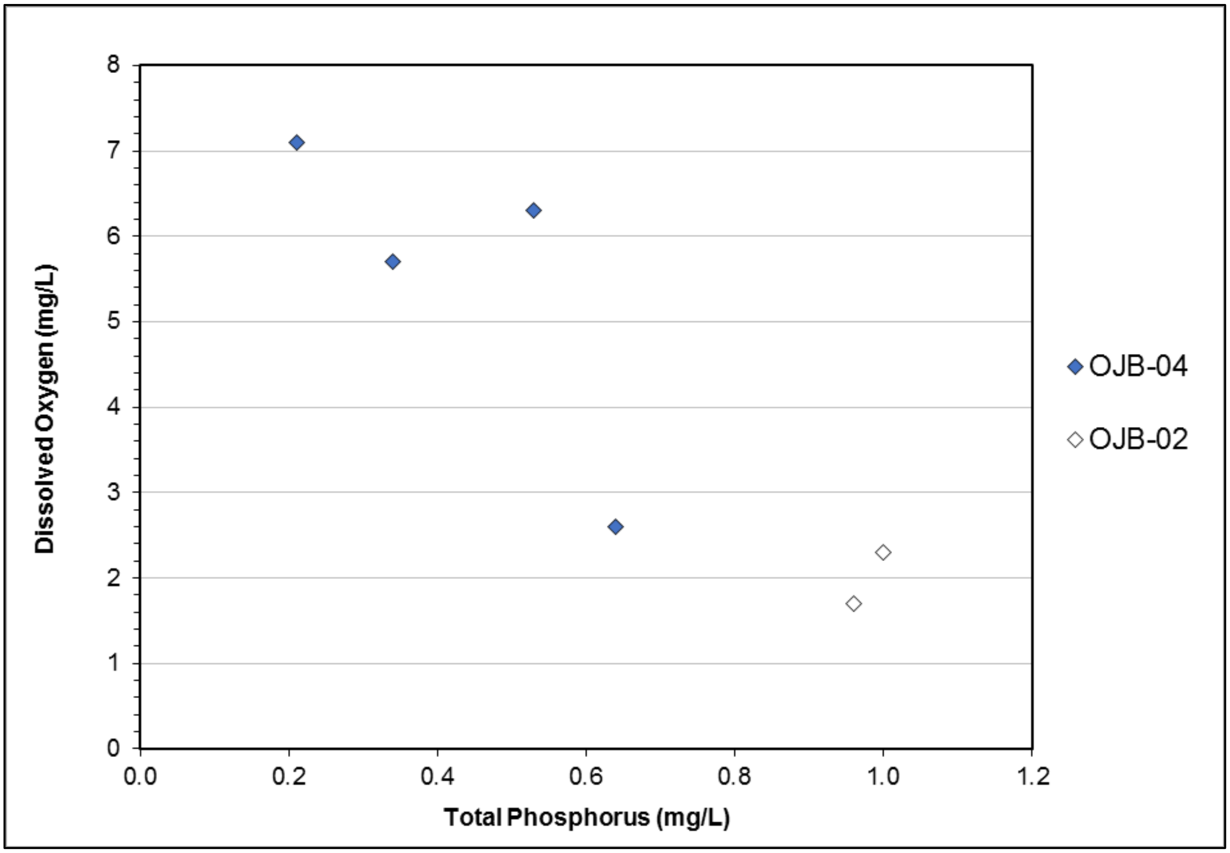

Figure 11. Total phosphorus versus dissolved oxygen—2002 and 2007, Lost Creek OJB-04.

4.6 Prairie Creek (OJBA)

Prairie Creek is listed as impaired for aquatic life due to dissolved oxygen along segment OJBA. There is one Illinois EPA sampling site located on segment OJBA. Three dissolved oxygen samples were collected on OJBA between 2007 and 2012 (Table 11 and Figure 12). One violation of the general use water quality standard for dissolved oxygen was observed in May 2007. However, to verify impairment on segments with fewer than ten samples, two or more violations of the general use water quality standard are needed. Therefore, additional data are needed to confirm impairment.

Table 11. Data Summary, Prairie Creek OJBA

Sample Site	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of violations of general use water quality standard (>5 mg/L (Mar-Jul) and >3.5 mg/L (Aug-Feb)
Dissolved oxygen					
OJBA-03	3	4.2	5.1	5.7	1

Further review of available information was conducted to evaluate the potential causes of impairment. There are several wastewater treatment facilities discharging to the segment that may be contributing to impairment (Table 6).

OJBA is also listed as impaired due to phosphorus (see Table 1). Three paired dissolved oxygen and phosphorus data points do not show a correlation. However, the data are too limited to draw conclusions.

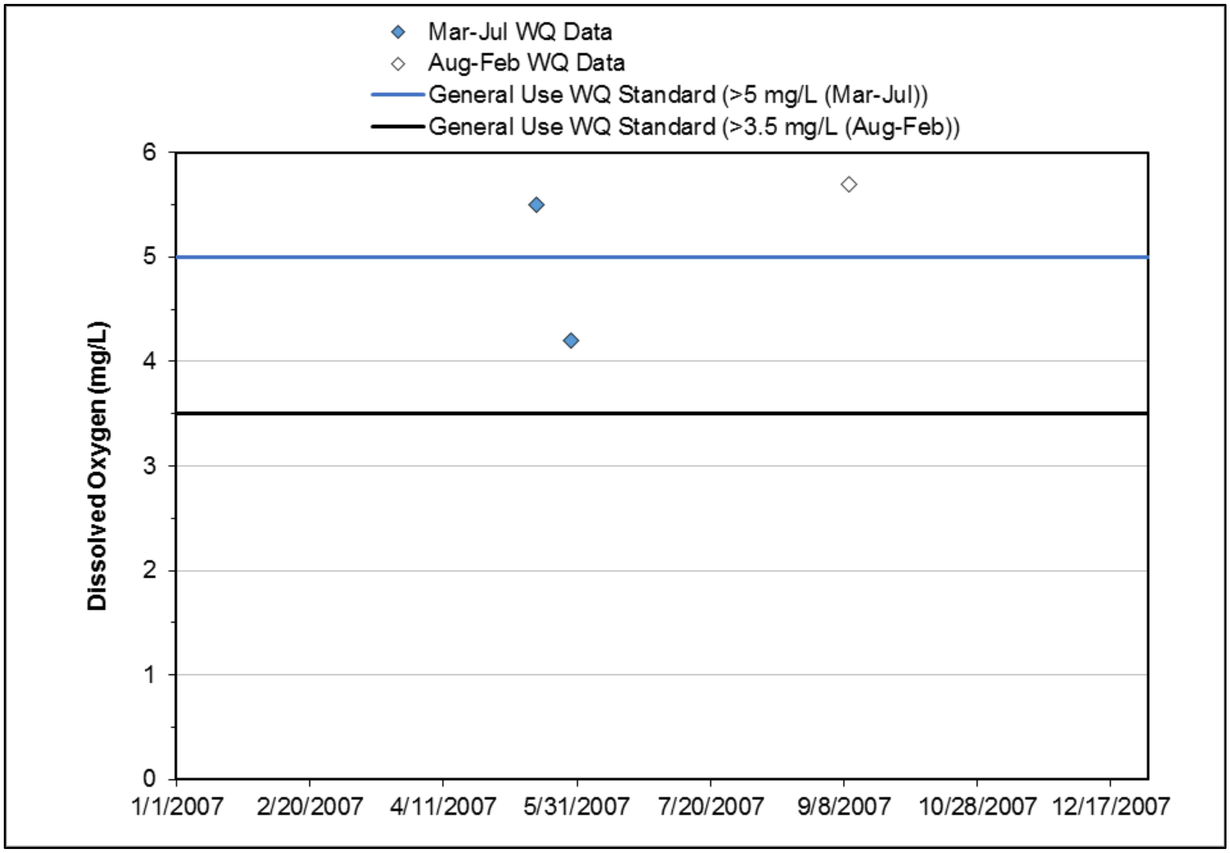

Figure 12. Dissolved oxygen water quality time series, Prairie Creek OJBA.

4.7 Grand Point Creek (OJC-01)

Grand Point Creek is listed as impaired for aquatic life due to dissolved oxygen along segment OJC-01. Three dissolved oxygen samples were collected on OJC-01 at sampling site OJC-03 (Table 12 and Figure 13). Two violations of the general use water quality standard for dissolved oxygen were observed in May and October 2007. Continuous dissolved oxygen data were collected in July and August 2017 (Figure 14). Greater than 10 percent of the samples and the 7-day mean during July 2017 violated the standard. Aquatic life use impairment is verified along this segment.

Table 12. Data summary, Grand Point Creek OJC-01

Sample Site	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of violations of general use water quality standard (>5 mg/L (Mar-Jul) and >3.5 mg/L (Aug-Feb))
Dissolved oxygen					
OJC-03	3	1.6	4.4	8.1	2

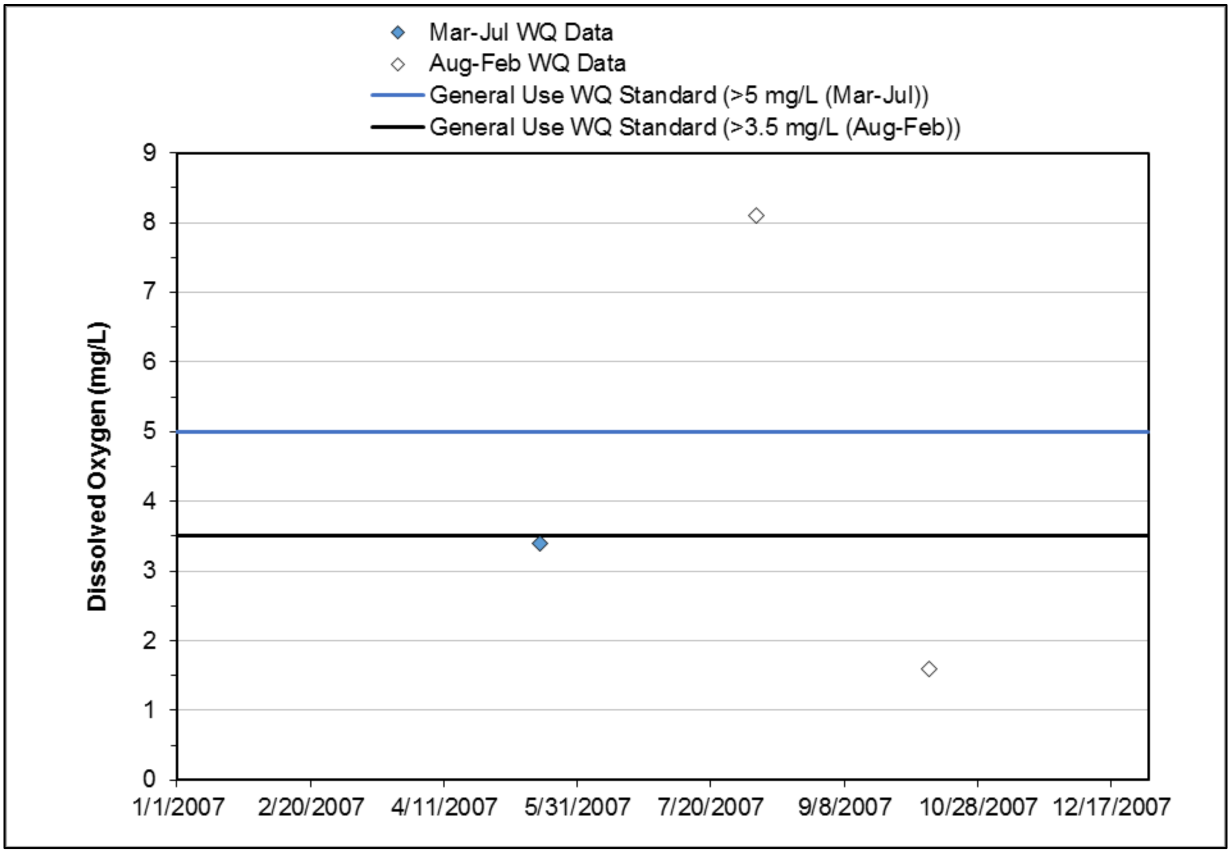

Figure 13. Dissolved oxygen water quality time series, Grand Point Creek OJC-01.

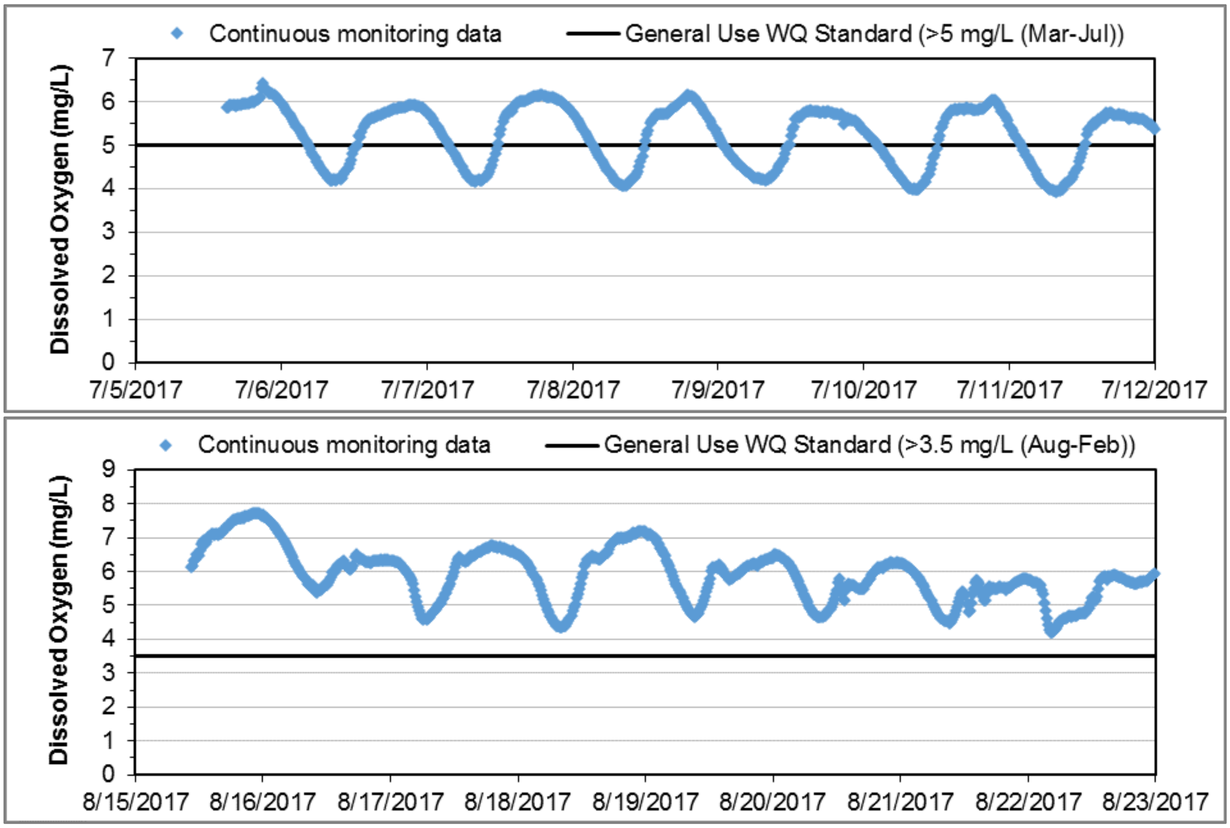

Figure 14. Continuous water quality time series for dissolved oxygen, Grand Point Creek OJC-01.

Further review of available information was conducted to determine the potential cause of impairment. No wastewater treatment facilities discharge to the segment. Sewer Creek (OJCB-19) is impaired for aquatic life due to phosphorus and sediment and is located upstream of impaired segment OJC-01; however, OJCB-19 discharges to an unimpaired segment prior to the confluence of Sewer Creek with Grand Point Creek. Dissolved oxygen data were paired with phosphorus data to determine if eutrophication is contributing to low dissolved oxygen conditions. There are only three paired dissolved oxygen and phosphorus data points, and based on this information it does not appear that eutrophication is influencing dissolved oxygen conditions. However, the data are too limited to draw conclusions.

4.8 Raccoon Creek (OJF)

Raccoon Creek is listed as impaired for aquatic life due to dissolved oxygen along segment OJF. There is one Illinois EPA sampling site located on segment OJF with dissolved oxygen data. Two dissolved oxygen samples were collected on OJF (Table 13). One violation of the general use water quality standard for dissolved oxygen was observed in June 2012 on the impaired segment OJF; however, to verify impairment on segments with fewer than ten samples, two or more violations of the general use water quality standard are needed. Therefore, additional data are needed to verify impairment.

Table 13. Data Summary, Raccoon Creek OJF

Sample Site	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of violations of general use water quality standard (>5 mg/L (Mar-Jul) and >3.5 mg/L (Aug-Feb))
Dissolved oxygen					
OJF-05	2	4.9	6.3	7.7	1

Further review of available information was conducted to determine the potential cause of impairment. No wastewater treatment facilities discharge to the segment. There are two sampling dates with both dissolved oxygen and phosphorus; the data are insufficient to determine if eutrophication is contributing to low dissolved oxygen conditions. No data were available for chlorophyll-*a*. Raccoon Creek segment OJF extends both downstream and upstream of Raccoon Lake, a reservoir created by damming Raccoon Creek. This hydromodification may also contribute to low dissolved oxygen levels.

4.9 Salem Lake (ROR)

Salem lake is listed as impaired for aquatic life due to pH; however, there are no pH data available. Available phosphorus data suggest that the lake is hypereutrophic, which can lead to high pH. Town Creek segment OJK-02, which begins north of Salem Lake (ROR) and ends just south of the lake, is impaired for aquatic life due to sediment. Segment OJK-03 of Town Creek, which is located just downstream of segment OJK-02, is impaired due to phosphorus. pH data are needed to confirm impairment.

5. TMDL Methods and Data Needs

The first stage of this project assesses available data followed by evaluation of their credibility. The types of data available, their quantity and quality, and their spatial and temporal coverage relative to impaired segments or watersheds drive the approaches used for TMDL model selection and analysis. Credible data are those that meet specified levels of data quality, with acceptance criteria defined by measurement quality objectives—specifically their precision, accuracy, bias, representativeness, completeness, and reliability. The following sections describe the methods that will be used to derive TMDLs and the additional data needed to develop credible TMDLs.

TMDLs are proposed for segments with verified impairments and known pollutants (Table 14). A duration curve approach is suggested to evaluate the relationships between hydrology and water quality and to calculate the TMDL for the the simazine impairment in O-25, if impairment is verified.

The Qual2K model is proposed to evaluate the confirmed low dissolved oxygen impairments where point sources are present. If point sources are not present and if there is a correlation with eutrophication (i.e., phosphorus concentration or high levels of algae and/or plant growth), a duration curve approach is suggested to develop a phosphorus TMDL. The phosphorus target will be derived from the relationship between phosphorus and dissolved oxygen in the impaired stream. TMDLs are not proposed for dissolved oxygen impairments that are not affected by point sources and do not show a correlation with eutrophication. In these cases, it is assumed that the cause of impairment is non-pollutant based (e.g., the effect of lack of re-aeration in low-gradient streams or the effect of hydromodification).

The Bathtub model is proposed to address the pH impairment in Salem Lake (ROR). pH is assumed to be linked to phosphorus concentrations in the lake.

Table 14. Proposed Model Summary

Name	Segment ID	Designated Uses	TMDL Parameter(s)	Proposed Model	Proposed Pollutant(s)
Kaskaskia River	IL_O-07	Aquatic life	Dissolved Oxygen	Load duration curve [a]	Phosphorus
	IL_O-25	Public and Food Processing Water Supply	Simazine	Load duration curve, pending impairment verification	Simazine
		Aquatic life	Dissolved Oxygen	Load duration curve [a]	Phosphorus
Crooked Creek	IL_OJ-07	Aquatic life	Dissolved Oxygen	QUAL2K, pending impairment verification (see section 5.4)	Biochemical oxygen demand, ammonia, and phosphorus
Crooked Creek	IL_OJ-11	Aquatic life	Dissolved Oxygen	Load duration curve or 4C classification, pending impairment verification (see section 5.4)	Phosphorus or non-pollutant
Lost Creek	IL_OJB-04	Aquatic Life	Dissolved Oxygen	Load duration curve	Phosphorus
Prairie Creek	IL_OJBA	Aquatic life	Dissolved Oxygen	Qual2K, pending impairment verification (see section 5.4)	Biochemical oxygen demand, ammonia, and phosphorus
Grand Point Creek	IL_OJC-01	Aquatic life	Dissolved Oxygen	Load duration curve or 4C classification	Phosphorus or non-pollutant
Raccoon Creek	IL_OJF	Aquatic life	Dissolved Oxygen	Load duration curve or 4C classification, pending impairment verification (see section 5.4)	Phosphorus or non-pollutant
Salem Lake	IL_ROR	Aquatic life	pH	Bathtub, pending impairment verification	Total phosphorus [b]

a. See section 5.1 for justification on the approach.
b. Available phosphorus data suggest that the lake is hypereutrophic, which can lead to violations of the pH standard. The proposed approach assumes that meeting the total phosphorus water quality standard for lakes of 0.05 mg/L will address the pH impairment.

5.1 Load Duration Curve Approach

The primary benefit of duration curves in TMDL development is to provide insight regarding patterns associated with hydrology and water quality concerns. The duration curve approach is particularly applicable because water quality is often a function of stream flow. For instance, sediment concentrations typically increase with rising flows as a result of factors such as channel scour from higher velocities. Other parameters, such as iron, may be more concentrated at low flows and more diluted by increased water volumes at higher flows. The use of duration curves in water quality assessment creates a framework that enables data to be characterized by flow conditions. The method provides a visual display of the relationship between stream flow and water quality.

Allowable pollutant loads have been determined through the use of load duration curves. Discussions of load duration curves are presented in *An Approach for Using Load Duration Curves in the Development of TMDLs* (U.S. EPA 2007). This approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from extremely high flows to extremely low flows.

2. The flow curve is translated into a load duration (or TMDL) curve by multiplying each flow value (in cubic feet per second) by the water quality standard/target for a contaminant (mg/L), then multiplying by conversion factors to yield results in the proper unit (e.g., pounds per day). The resulting points are plotted to create a load duration curve.

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected. Then, the individual loads are plotted as points on the TMDL graph and can be compared to the water quality standard/target, or load duration curve.

4. Points plotting above the curve represent deviations from the water quality standard/target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load. Further, it can be determined which locations contribute loads above or below the water quality standard/target.

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards/targets.

6. The final step is to determine where reductions need to occur. Exceedances at the right side of the graph occur during low flow conditions and may be derived from sources such as illicit sewer connections. Exceedances on the left side of the graph occur during higher flow events and may be derived from sources such as runoff. Using the load duration curve approach allows Illinois EPA to determine which implementation practices are most effective for reducing loads on the basis of flow regime.

Water quality duration curves are created using the same steps as those used for load duration curves except that concentrations, rather than loads, are plotted on the vertical axis. Flows are categorized into the following five hydrologic zones (U.S. EPA 2007):

- High flow zone: stream flows that plot in the 0 to 10-percentile range, related to flood flows
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions
- Mid-range zone: flows in the 40 to 60-percentile range, median stream flow conditions
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions

The duration curve approach helps to identify the issues surrounding the impairment and to roughly differentiate among sources. Table 15 summarizes the general relationship between the five hydrologic zones and potentially contributing source areas (the table is not specific to any individual pollutant). For example, the table indicates that impacts from point sources are usually most pronounced during dry and low flow zones because there is less water in the stream to dilute their loads. In contrast, impacts from stormwater are most pronounced during moist and high flow zones due to increased overland flow from stormwater source areas during rainfall events.

Table 15. Relationship between duration curve zones and contributing sources

Contributing source area	Duration Curve Zone				
	High	Moist	Mid-range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
Onsite wastewater systems	M	M-H	H	H	H
Stormwater: Impervious		H	H	H	
Stormwater: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	

Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low).

The load reduction approach also considers critical conditions and seasonal variation in the TMDL development as required by the Clean Water Act and U.S. EPA's implementing regulations. Because the approach establishes loads on the basis of a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions. An underlying premise of the duration curve approach is correlation of water quality impairments to flow conditions. The duration curve alone does not consider specific fate and transport mechanisms, which may vary depending on watershed or pollutant characteristics.

Phosphorus TMDLs will be developed with the load duration curve approach for the dissolved oxygen impairments on Kaskaskia River segments IL_O-07 and IL_O-25. In both segments, there is a relationship between phosphorus and DO (Figure 4 and Figure 6), suggesting that eutrophication is an issue on the segments. The relationship can be used to derive a phosphorus target for the dissolved oxygen impairments. Although there is a point source (Carlyle STP–IL0027901) that discharges to segment IL_O-07, the flow and phosphorus load from the point source are minimal compared to the flow and load in the Kaskaskia River. Additionally, a phosphorus TMDL is being developed for Carlyle Reservoir, which is directly upstream of segment IL_O-07, and substantial P reductions will be needed to meet the Carlyle Reservoir phosphorus TMDL.

5.2 Qual2K

Qual2K is a steady-state water quality model that simulates eutrophication kinetics and conventional water quality parameters and is maintained by U.S. EPA. Qual2K simulates up to 15 water quality constituents in branching stream systems. A stream reach is divided into a number of computational elements, and for each computational element a hydrologic balance in terms of stream flow (e.g., m^3/s), a heat balance in terms of temperature (e.g., degrees C), and a material balance in terms of concentration (e.g., mg/l) are written. Both advective and dispersive transport processes are considered in the material balance. Mass is gained or lost from the computational element by transport processes, wastewater discharges, and withdrawals. Mass can also be gained or lost by internal processes such as release of mass from benthic sources or biological transformations.

The program simulates changes in flow conditions along the stream by computing a series of steady-state water surface profiles. The calculated stream-flow rate, velocity, cross-sectional area, and water depth serve as a basis for determining the heat and mass fluxes into and out of each computational element due to flow. Mass balance determines the concentrations of constituents at each computational element. In addition to material fluxes, major processes included in the mass balance are transformation of nutrients, algal production, benthic and carbonaceous oxygen demand, atmospheric reaeration, and the effect of these processes on the dissolved oxygen balance. The nitrogen cycle is divided into four compartments:

organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. The primary internal sink of dissolved oxygen in the model is biochemical oxygen demand (BOD). The major sources of dissolved oxygen are algal photosynthesis and atmospheric reaeration.

The model is applicable to dendritic streams that are well mixed. It assumes that the major transport mechanisms, advection and dispersion, are significant only along the main direction of flow (the longitudinal axis of the stream). It allows for multiple waste discharges, withdrawals, tributary flows, and incremental inflow and outflow.

Hydraulically, Qual2K is limited to the simulation of time periods during which both the stream flow in river basins and input waste loads are essentially constant. Qual2K can operate as either a steady-state or a quasi-dynamic model, making it a very helpful water quality planning tool. When operated as a steady-state model, it can be used to study the impact of waste loads (magnitude, quality, and location) on instream water quality. By operating the model dynamically, the user can study the effects of diurnal variations in meteorological data on water quality (primarily dissolved oxygen and temperature) and also can study diurnal dissolved oxygen variations due to algal growth and respiration. However, the effects of dynamic forcing functions, such as headwater flows or point loads, cannot be modeled in Qual2K. A steady-state model is proposed for all segments.

Qual2K is an appropriate choice for organic enrichment TMDLs that can be implemented at a moderate level of effort. Use of the Qual2K models in TMDLs is most appropriate when (1) full vertical mixing can be assumed, and (2) water quality excursions are associated with identifiable critical flow conditions. Because these models do not simulate dynamically varying flows, their use is limited to evaluating responses to one or more specific flow conditions. The selected flow condition should reflect critical conditions, which for dissolved oxygen occurs when flows are low and the ambient air temperature is warm, typically in July or August.

5.3 Bathtub

The Bathtub model is proposed to support TMDL development for Salem Lake. Bathtub is a steady state model that predicts eutrophication response in lakes based on empirical formulas developed for nutrient balance calculations and algal response (Walker 1987). The model was developed and is maintained by the U.S. Army Corps of Engineers. The model requires nutrient loading inputs from the watershed and atmospheric deposition, lake morphometric data, and estimates of mixing depth and nonalgal turbidity.

Due to a lack of available inflow monitoring data, watershed inputs will be derived from *Spreadsheet Tool for the Estimation of Pollutant Load* (STEPL). STEPL provides a simplified simulation of precipitation-driven runoff and sediment and nutrient delivery. STEPL can estimate loads from land uses, as well as from other sources such as stream bank erosion and failing septic systems. STEPL simulates runoff and stream flow using summary information on precipitation and rain days for the nearest weather station. STEPL has been used extensively in Region 5 for watershed plan development and in support of watershed studies. STEPL is an appropriate model to evaluate the relative contribution of various sources of pollutants and allows for the identification of the priority sources of pollutants for evaluation during implementation planning. STEPL also provides the level of detail needed for external watershed loading to Salem Lake that is required for Bathtub input.

Similar to most modeling applications, the Bathtub model is first calibrated to available data and then used to determine the load reductions that are needed to meet water quality standards. In this case, it is assumed that meeting the Illinois lake water quality standard for total phosphorus will result in bringing the lake’s pH into compliance.

5.4 Additional Data Needs

Data satisfy two key objectives for Illinois EPA, enabling the agency to make informed decisions about the resource. These objectives include developing information necessary to:

- Determine if the impaired areas meet applicable water quality standards for their respective designated use(s)
- Support modeling and assessment activities required to allocate pollutant loadings for all impaired areas where water quality standards are not being met

Additional data may be needed to verify impairment, understand probable sources, calculate reductions, develop calibrated water quality models, and develop effective implementation plans. Table 16 summarizes the additional data needed for each impaired segment.

Table 16. Additional water quality data needs

Name	Segment ID	Designated Uses	TMDL Parameters	Additional Data Needs
Kaskaskia River	IL_O-07	Aquatic Life	Dissolved Oxygen	Potentially, to confirm relationship with eutrophication
	IL_O-25	Public and Food Processing Water Supply	Simazine	Yes, to confirm impairment
		Aquatic Life	Dissolved Oxygen	Potentially, to confirm relationship with eutrophication
Crooked Creek	IL_OJ-07	Aquatic Life	Dissolved Oxygen	Yes, to confirm impairment and to support Qual2K model
Crooked Creek	IL_OJ-11	Aquatic Life	Dissolved Oxygen	Yes, to confirm impairment and to determine relationship with eutrophication
Lost Creek	IL_OJB-04	Aquatic Life	Dissolved Oxygen	None
Prairie Creek	IL_OJBA	Aquatic Life	Dissolved Oxygen	Yes, to confirm impairment and to support Qual2K model
Grand Point Creek	IL_OJC-01	Aquatic Life	Dissolved Oxygen	Yes, to determine relationship with eutrophication
Raccoon Creek	IL_OJF	Aquatic Life	Dissolved Oxygen	Yes, to confirm impairment and to determine relationship with eutrophication
Salem Lake	IL_ROR	Aquatic Life	pH	Yes, to confirm impairment; optional data collection to determine relationship with eutrophication

Specific data needs include:

Confirm Simazine Impairment on IL_O-25—Simazine sampling is recommended during spring 2019 to confirm impairment. Three to five samples should be collected at O-25 during April, May, and June to provide a spring quarterly average that can be compared against the target. Simazine is typically applied as early as 30 days prior to planting, and after planting but before the crop reaches 5 inches in height (ISU Extension 2005).

Confirm Relationship with Eutrophication on IL_O-07 and IL_O-25—If additional data are necessary to confirm the relationship between phosphorus and dissolved oxygen, collect DO, chlorophyll-

a, and TP grab samples at stations O-07 and O-25; two samples per day (one per day in the early morning) on three separate sampling days, during the warm summer months (July–August) and during low flows.

Confirm Dissolved Oxygen Impairment and Support Qual2K Model Development on IL_OJ-07— A minimum of two monitoring stations are needed on the impaired segment, in addition to monitoring stations at substantial tributaries. The following sites are recommended: 1) OJ-01, 2) OJ-13, and 3) a new site on Turkey Creek where it crosses US Highway 51 near the outlet. Ideally, there would be two separate data collection periods, each time period lasting roughly one week during critical conditions (low flow, warm conditions). Although these locations are a minimum, adding more locations along the reach of interest will help determine how heterogeneous the system is and what dynamics are occurring along the reach. Monitoring stations can be located downstream of key tributaries, at road crossings, etc. as deemed necessary.

Recommended monitoring to support Qual2K development includes various types of data:

- Continuous dissolved oxygen, stream temperature, conductivity, and pH monitoring during a warm, low flow period in July; monitoring should take place over approximately two weeks at a minimum of two locations.
- Flow measurements (depth and velocity) during dissolved oxygen monitoring at least twice at two locations; the number of measurements will be dependent on weather and stream conditions.
- Multiple samples of organic nitrogen, ammonia nitrogen, nitrate nitrogen, organic phosphorus, soluble reactive phosphorus, total inorganic carbon, carbonaceous biochemical oxygen demand (5-day and 20-day if possible), inorganic solids, chlorophyll-*a*, and alkalinity. Depending on the monitoring station, grab samples could be collected twice per day during the first and last days of sonde deployment or throughout the week.
- Macrophyte and attached algae survey, survey of groundwater and tributary contributions, if any.
- Channel geometry, shade/vegetative survey, cloud cover, and channel substrate and bottom material, both upstream and downstream of the monitoring stations(s).
- A longitudinal/synoptic survey of DO concentrations along the entire reach (hand-sampling by probe on foot or from a row-boat periodically along the entire reach extent).
- Funding permitted: *in-situ* measurements of stream reaeration (via diffusion dome technique) and *in-situ* measurements of sediment oxygen demand (via chambers deployed on the streambed). Sediment bed surveys can be conducted potentially in lieu of sediment oxygen demand (SOD) sampling (sediment total organic carbon sampling for instance could be a rough proxy for SOD if needed).
- Photo documentation of the system.

Confirm Dissolved Oxygen Impairment(s) and Determine Relationship with Eutrophication on IL_OJ-11 and IL_OJF (no wastewater treatment facilities discharging to segments)—Collect DO, chlorophyll-*a*, and TP grab samples at stations OJ-11 and OJF; two samples per day (one per day in the early morning) on three separate sampling days, during the warm summer months (July–August) and during low flows.

Determine Relationship with Eutrophication on IL_OJC-01—Collect DO, chlorophyll-*a*, and TP grab samples at station OJC-03; two samples per day (one per day in the early morning) on three separate sampling days, during the warm summer months (July–August) and during low flows.

Confirm Dissolved Oxygen Impairment and Support Qual2K Model Development on IL_OJBA—A minimum of two monitoring stations are needed on the impaired segment. Ideally, there would be two separate data collection periods, each time period lasting roughly one week during critical conditions (low flow, warm conditions). Although two monitoring locations are a minimum, adding more locations along the reach of interest will help determine how heterogeneous the system is and what dynamics are occurring along the reach. Monitoring stations can be located downstream of key tributaries, at road crossings, etc. as deemed necessary.

Recommended monitoring to support Qual2K development includes various types of data:

- Continuous dissolved oxygen, stream temperature, conductivity, and pH monitoring during a warm, low flow period in July; monitoring should take place over approximately two weeks at a minimum of two locations.
- Flow measurements (depth and velocity) during dissolved oxygen monitoring at least twice at two locations; the number of measurements will be dependent on weather and stream conditions.
- Multiple samples of organic nitrogen, ammonia nitrogen, nitrate nitrogen, organic phosphorus, soluble reactive phosphorus, total inorganic carbon, carbonaceous biochemical oxygen demand (5-day and 20-day if possible), inorganic solids, chlorophyll-*a*, and alkalinity. Depending on the monitoring station, grab samples could be collected twice per day during the first and last days of sonde deployment or throughout the week.
- Macrophyte and attached algae survey, survey of groundwater and tributary contributions, if any.
- Channel geometry, shade/vegetative survey, cloud cover, and channel substrate and bottom material, both upstream and downstream of the monitoring stations(s).
- A longitudinal/synoptic survey of DO concentrations along the entire reach (hand-sampling by probe on foot or from a row-boat periodically along the entire reach extent).
- Funding permitted: *in-situ* measurements of stream reaeration (via diffusion dome technique) and *in-situ* measurements of sediment oxygen demand (via chambers deployed on the streambed). Sediment bed surveys can be conducted potentially in lieu of sediment oxygen demand (SOD) sampling (sediment total organic carbon sampling for instance could be a rough proxy for SOD if needed).
- Photo documentation of the system.

Confirm pH Impairment in Salem Lake—Field monitoring of pH using a hand-held sonde should be conducted during the growing season in Salem Lake. Measurements should be made at least twice per month throughout the growing season and should be taken in the afternoon, when rates of photosynthesis are highest and pH is most likely to be high. Additional phosphorus and chlorophyll-*a* samples are suggested to pair with the pH measurements.

Implementation Plan Development—Further in-field assessment may be needed to better determine the source of impairments in order to develop an effective TMDL implementation plan. Additional monitoring includes:

- Synoptic sampling in additional upstream impairments to determine impacts to impairments in this TMDL
- Wind shield surveys
- Streambank surveys
- Stream assessments
- Farmer/landowner surveys
- Word of mouth and in-person conversations with local stakeholders and landowners

6. Public Participation

<to be updated based on Stage 1 meetings>

7. References

Horsley and Witten, Inc. 1996. Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine. Casco Bay Estuary Project.

Illinois EPA (Illinois Environmental Protection Agency). 1994. Quality Assurance Project Plan. Bureau of Water, Division of Water Pollution Control. Springfield, Illinois.

Illinois EPA (Illinois Environmental Protection Agency) 2008. Crooked Creek Watershed Total Maximum Daily Load. http://www.epa.state.il.us/water/tmdl/report/crooked-creek/crooked-creek.pdf

Illinois EPA (Illinois Environmental Protection Agency). 2016. Draft Illinois Integrated Water Quality Report and Section 303(d) List, 2016. Water Resource Assessment Information and Listing of Impaired Waters. Springfield, IL.

ISU Extension (Iowa State University Extension). 2005. *2005 Herbicide Manual for Agricultural Professionals*. ISU Extension Agronomy, 2104 Agronomy Hal, Ames, Iowa 50011.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing Biological Integrity in Running Water: a Method and its Rationale. Illinois Natural History Survey Special Publication 5. Champaign, Illinois.

MRLC (Multi-Resolution Land Characteristics Consortium). 2015. National Land Cover Database (NLCD 2011). Retrieved from: http://www.mrlc.gov.

Smogor, R. 2000 (draft, annotated 2006). Draft manual for Calculating Index of Biotic Integrity Scores for Streams in Illinois. Illinois Environmental Protection Agency, Bureau of Water, Division of Water Pollution Control. Springfield, Illinois.

Smogor, R. 2005 (draft). Interpreting Illinois fish-IBI Scores. Illinois Environmental Protection Agency, Bureau of Water, Division of Water Pollution Control. Springfield, Illinois.

Southwestern Illinois RC&D, Inc. 2002. Kaskaskia River Watershed, An Ecosystem Approach to Issues and Opportunities. Developed in cooperation with and funding provided by the Illinois Department of Natural Resources and U.S. Army Corps of Engineers.

Tetra Tech. 2004. Illinois Benthic Macroinvertebrate Collection Method Comparison and Stream Condition Index Revision, 2004.

U.S. EPA (U.S. Environmental Protection Agency). 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. EPA 440/4-91-001. Office of Water, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 2002. National Recommended Water Quality Criteria: 2002. EPA-822-R-02-047. Office of Water. Office of Science and Technology. Washington, D.C.

U.S. EPA (U.S. Environmental Protection Agency). 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006. U.S. Environmental Protection Agency, Washington D.C.

USDA (U.S. Department of Agriculture) 1990. Soil Conservation Service. Pesticide Properties Database: Version 2.0 (Summary). USDA–Soil Conservation Service, Syracuse, NY.

Walker, W.W. 1987. Empirical Methods for Predicting Eutrophication in Impoundments. Report 4, Applications Manual, Tech. Rep. E-81-9. Prepared for U.S. Army Corps of Engineers Waterways Exp. Sta. Vicksburg, MS.

Appendix A – Unimpaired Stream Data Analysis

Crooked Creek (IL_OJ-08)

Crooked Creek is listed as impaired for aquatic life due to iron along segment IL_OJ-08. There were 72 iron samples collected on OJ-08 during the period of record (Table 17**Error! Reference source not found.** and Figure 15**Error! Reference source not found.**). One exceedance of the general use water quality standard for iron was observed in August 2011. No wastewater treatment facilities discharge to the segment. Because only one exceedance was observed, a TMDL is not being developed.

Table 17. Data summary, Crooked Creek OJ-08

Sample Site	No. of samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Number of exceedances of general use water quality standard (1,000 µg/L)
Iron					
OJ-08	72	13	158	1,050	1

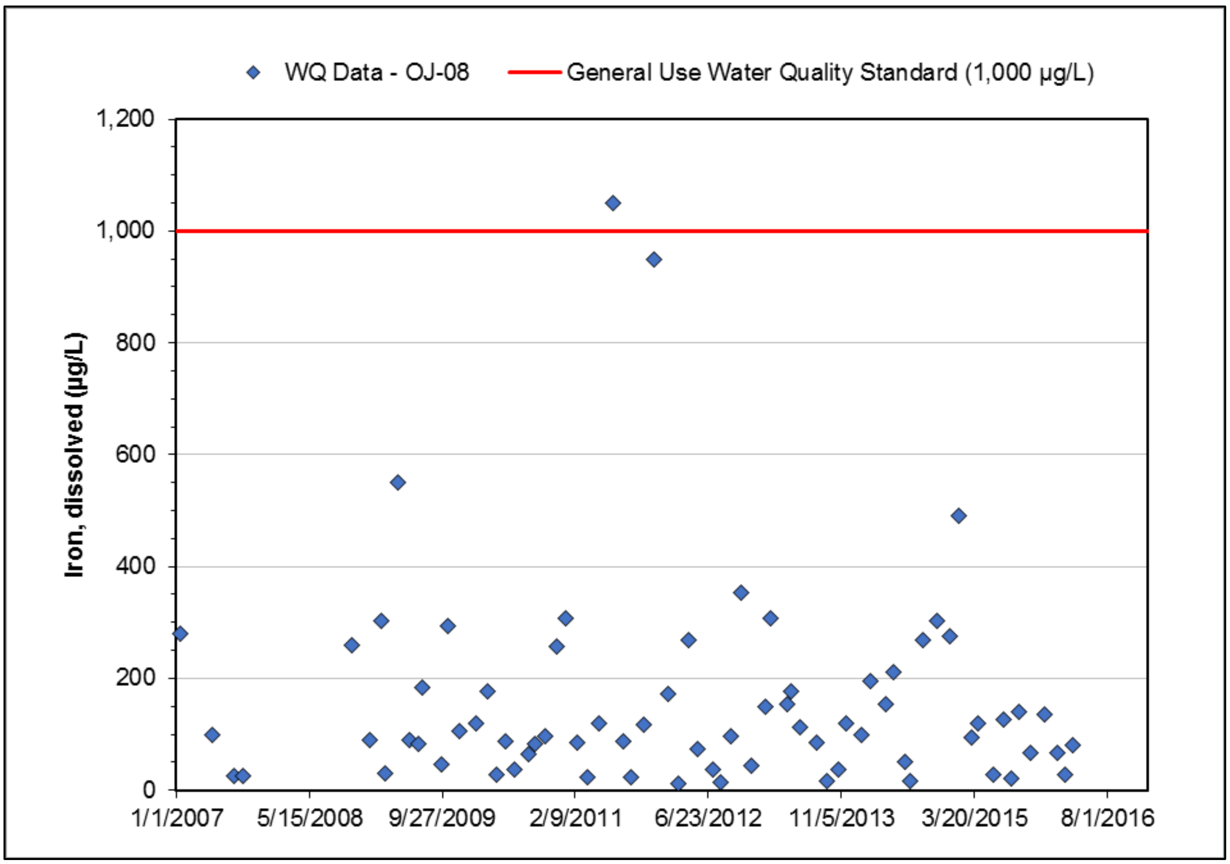

Figure 15. Dissolved iron water quality time series, Crooked Creek OJ-08.